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User's Manual

M3T-MR30 V.3.30

User's Manual

Real-time OS for M16C/60,30,20,10 Series

Renesas Electronics
www.renesas.com

Rev.1.00 2003.09

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Preface

The MR30 is a real-time operating system[1] for the M16C microcomputers. The MR30 conforms to the µITRON Specification.[2]

This manual describes the procedures and precautions to observe when you use the MR30 for programming purposes. For the detailed information on individual system call procedures, refer to the MR30 Reference Manual.

Requirements for MR30 Use

When creating programs based on the MR30, it is necessary to purchase the following product of Renesas.

- C-compiler M3T-NC30WA for M16C/60,30,20,10 Series
  When these related products are used, increased program development efficiency is obtained.

Document List

The following sets of documents are supplied with the MR30.

- Release Note
  Presents a software overview and describes the corrections to the Users Manual and Reference Manual.

- Users Manual (PDF file)
  Describes the procedures and precautions to observe when using the MR30 for programming purposes.

- Reference Manual (PDF file)
  Describes the MR30 system call procedures and typical usage examples. Before reading the Users Manual, be sure to read the Release Note.

  Please read the release note before reading this manual.

Right of Software Use

The right of software use conforms to the software license agreement. You can use the MR30 for your product development purposes only, and are not allowed to use it for the other purposes. You should also note that this manual does not guarantee or permit the exercise of the right of software use.

[1] Hereinafter abbreviated "real-time OS"

[2] The µITRON Specification is originated by Dr.Ken Sakamura and his laboratory members at the Faculty Science of University of Tokyo. Therefore,Dr.Ken Sakamura holds the copyright on the µITRON Specification. By his consent,the MR30 is produced in compilance with the µITRON Specification.

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Chapter 1 User's Manual Organization

The MR30 User's Manual consists of nine chapters and thee appendix.

- Chapter 2 General Information
  Outlines the objective of MR30 development and the function and position of the MR30.

- Chapter 3 Introduction to MR30
  Explains about the ideas involved in MR30 operations and defines some relevant terms.

- Chapter 4 Applications Development Procedure Overview
  Outlines the applications program development procedure for the MR30.

- Chapter 5 Detailed Applications
  Details the applications program development procedure for the MR30.

- Chapter 6 Using Configurator
  Describes the method for writing a configuration file and the method for using the configurator in detail.

- Chapter 7 Application Creation Guide
  Presents useful information and precautions concerning applications program development with MR30.

- Chapter 8 Sample Program Description
  Describes the MR30 sample applications program which is included in the product in the form of a source file.

- Chapter 9 Separate ROMs
  Explains about how to Form Separate ROMs.

Chapter 2 General Information

2.1 Objective of MR30 Development

In line with recent rapid technological advances in microcomputers, the functions of microcomputer-based products have become complicated. In addition, the microcomputer program size has increased. Further, as product development competition has been intensified, manufacturers are compelled to develop their microcomputer-based products within a short period of time.

In other words, engineers engaged in microcomputer software development are now required to develop larger-size programs within a shorter period of time. To meet such stringent requirements, it is necessary to take the following considerations into account.

1. **To enhance software recyclability to decrease the volume of software to be developed.**

   One way to provide for software recyclability is to divide software into a number of functional modules wherever possible. This may be accomplished by accumulating a number of general-purpose subroutines and other program segments and using them for program development. In this method, however, it is difficult to reuse programs that are dependent on time or timing. In reality, the greater part of application programs are dependent on time or timing. Therefore, the above recycling method is applicable to only a limited number of programs.

2. **To promote team programming so that a number of engineers are engaged in the development of one software package**

   There are various problems with team programming. One major problem is that debugging can be initiated only when all the software program segments created individually by team members are ready for debugging. It is essential that communication be properly maintained among the team members.

3. **To enhance software production efficiency so as to increase the volume of possible software development per engineer.**

   One way to achieve this target would be to educate engineers to raise their level of skill. Another way would be to make use of a structured descriptive assembler, C-compiler, or the like with a view toward facilitating programming. It is also possible to enhance debugging efficiency by promoting modular software development.

However, the conventional methods are not adequate for the purpose of solving the problems. Under these circumstances, it is necessary to introduce a new system named real-time OS [3]

To answer the above-mentioned demand, Renesas has developed a real-time operating system, tradenamed MR30, for use with the M16C/60 Series 16-bit one-chip microcomputers.

When the MR30 is introduced, the following advantages are offered.

1. **Software recycling is facilitated.**

   When the real-time OS is introduced, timing signals are furnished via the real-time OS so that programs dependent on timing can be reused. Further, as programs are divided into modules called tasks, structured programming will be spontaneously provided.

   That is, recyclable programs are automatically prepared.

2. **Ease of team programming is provided.**

   When the real-time OS is put to use, programs are divided into functional modules called tasks. Therefore, engineers can be allocated to individual tasks so that all steps from development to debugging can be conducted independently for each task.

   Further, the introduction of the real-time OS makes it easy to start debugging some already finished tasks even if the entire program is not completed yet. Since engineers can be allo-

[3] OS:Operating System

cated to individual tasks, work assignment is easy.

3. Software independence is enhanced to provide ease of program debugging.

As the use of the real-time OS makes it possible to divide programs into small independent modules called tasks, the greater part of program debugging can be initiated simply by observing the small modules.

4. Timer control is made easier.

To perform processing at 10 ms intervals, the microcomputer timer function was formerly used to periodically initiate an interrupt. However, as the number of usable microcomputer timers was limited, timer insufficiency was compensated for by, for instance, using one timer for a number of different processing operations.

When the real-time OS is introduced, however, it is possible to create programs for performing processing at fixed time intervals making use of the real-time OS time management function without paying special attention to the microcomputer timer function. At the same time, programming can also be done in such a manner as to let the programmer take that numerous timers are provided for the microcomputer.

5. Software maintainability is enhanced

When the real-time OS is put to use, the developed software consists of small program modules called tasks. Therefore, increased software maintainability is provided because developed software maintenance can be carried out simply by maintaining small tasks.

6. Increased software reliability is assured.

The introduction of the real-time OS makes it possible to carry out program evaluation and testing in the unit of a small module called task. This feature facilitates evaluation and testing and increases software reliability.

7. The microcomputer performance can be optimized to improve the performance of microcomputer-based products.

With the real-time OS, it is possible to decrease the number of unnecessary microcomputer operations such as I/O waiting. It means that the optimum capabilities can be obtained from microcomputers, and this will lead to microcomputer-based product performance improvement.

2.2 Relationship between TRON Specification and MR30

The TRON Specification is an abbreviation for The Real-time Operating system Nucleus specification. It denotes the specifications for the nucleus of a real-time operating system. The TRON Project, which is centered on TRON Specification design, is pushed forward under the leadership of Dr. Ken Sakamura at Faculty of Science, University of Tokyo.

As one item of this TRON Project, the ITRON Specification is promoted. The ITRON Specification is an abbreviation for the Industrial TRON Specification. It denotes the real-time operating system that is designed with a view toward establishing industrial real-time operating systems.

The ITRON Specification provides a number of functions to properly meet the application requirements. In other words, ITRON systems require relatively large memory capacities and enhanced processing capabilities. The μITRON Specification V.2.0 is the arranged version of the ITRON Specification for the higher processing speed, and incorporated only a minimum of functions necessary. The μITRON Specification V.2.0 can be said to be a subset of the ITRON Specification for the following reasons.

1. **The system call time-out function is not incorporated.**

2. **Tasks, semaphores, and other objects can be generated only at the time of system generation.[4] They cannot be generated after system startup.[5]**

3. **Only memorypools of a fixed-size can be handled. Memorypools of a variable-size cannot be handled.**

4. **Neither the system call exception management function nor the CPU exception management function is provided.**

Currently stipulated are μITRON specifications V.3.0. The μITRON specifications V.3.0 provides enhanced connection functions by integrating μITRON specifications V.2.0 and ITRON specifications. MR30 is a real-time operating system developed for the M16C/60 Series series of 16-bit microprocessors according to the μITRON specification.4[6] The μITRON specifications V.3.0 has its system calls classified into level R, level S,level E, and level C.

MR30 implements all of level R and level S system calls and part of level E system calls among those stipulated under μITRON specifications V.3.0.

The MR30 specifications are outlined in Table 2.1.

[4] Static object generation.
[5] Dynamic object generation
[6] MR30 V.1.00 conforms to μITRON Specifications V.3.0.

Table 2.1 MR30 Specifications Overview

Item	Specifications
Target microprocessor	M16C/60,30,20,10 series microcomputers
Maximum number of tasks	255
Task priorities	255
Maximum number of eventflags	255
Eventflag width	16 bit
Maximum number of semaphores	255
Semaphore type	Counter type
Maximum number of mailboxes	255
Message size	16 bit or 32 bit
Buffer size of Mailbox	more than 0 byte
Maximum number of Fixed-size Memorypool	255
Maximum number of Variable-size Memorypool	1
Number of system calls	61
OS nucleus code size OS nucleus data size OS nucleus language	Approx. 1.0K to 10.0K bytes 16bytes min., 11byte increment per task (except stack) In addition, if you use timeout function, increased 15byte per task. C and Assembly language

2.3 MR30 Features

The MR30 offers the following features.

1. **Real-time operating system conforming to the μITORN Specification.**

   The MR30 is designed in compliance with the μITRON Specification which incorporates a minimum of the ITRON Specification functions so that such functions can be incorporated into a one-chip microcomputer. As the μITRON Specification is a subset of the ITRON Specification, most of the knowledge obtained from published ITRON textbooks and ITRON seminars can be used as is.

   Further, the application programs developed using the real-time operating systems conforming to the ITRON Specification can be transferred to the MR30 with comparative ease.

2. **High-speed processing is achieved.**

   MR30 enables high-speed processing by taking full advantage of the microcomputer architecture.

3. **Only necessary modules are automatically selected to constantly build up a system of the minimum size.**

   The MR30 is supplied in the form of a M16C/60 series microcomputer objective library.

   Therefore, the Linkage Editor LN30 functions are activated so that only necessary modules are automatically selected from numerous MR30 functional modules to generate a system.

   Thanks to this feature, a system of the minimum size is automatically generated at all times.

4. **With the C-compiler NC30, it is possible to develop application programs in C language.**

   When the C-compiler NC30 is used, MR30 application programs can be developed in C language.Also note that an interface library is supplied on software disk to permit calling up the MR30 functions in C language.

5. **An upstream process tool named "Configurator" is provided to simplify development procedures**

   A configurator is furnished so that various items including a ROM write form file can be created by giving simple definitions.

   Therefore, there is no particular need to care what libraries must be linked.

Chapter 3 Introduction to MR30

3.1 Concept of Real-time OS

This section explains the basic concept of real-time OS.

3.1.1 Why Real-time OS is Necessary

In line with the recent advances in semiconductor technologies, the single-chip microcomputer ROM capacity has increased. ROM capacity of 32K bytes.

As such large ROM capacity microcomputers are introduced, their program development is not easily carried out by conventional methods. Fig.3.1 shows the relationship between the program size and required development time (program development difficulty).

This figure is nothing more than a schematic diagram. However, it indicates that the development period increases exponentially with an increase in program size.

For example, the development of four 8K byte programs is easier than the development of one 32K byte program.[7]

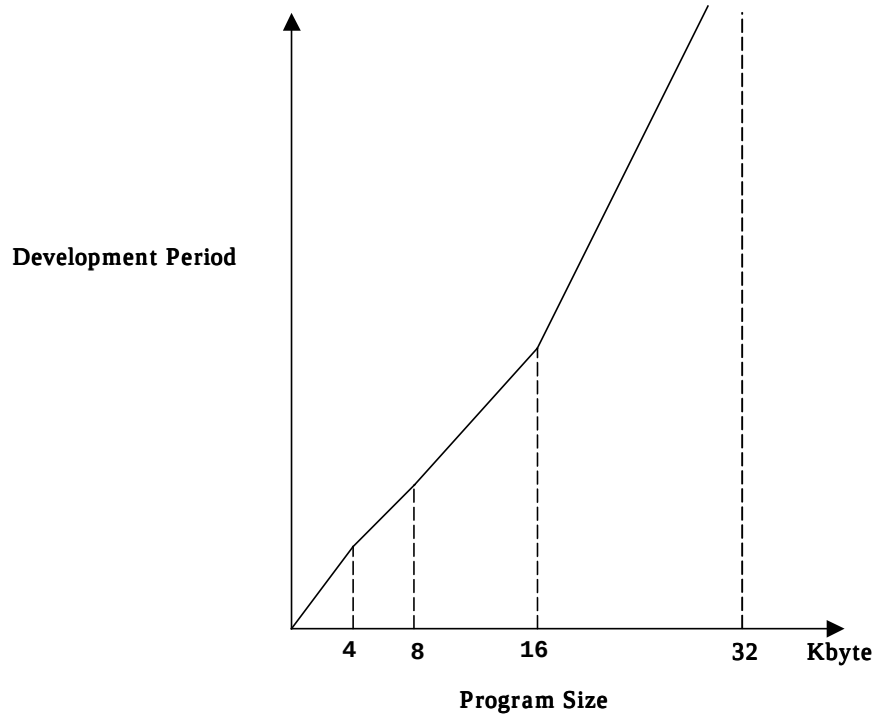


Figure 3.1 Relationship between Program Size and Development Period

Under these circumstances, it is necessary to adopt a method by which large-size programs can be developed within a short period of time. One way to achieve this purpose is to use a large number of microcomputers having a small ROM capacity. Figure 3.2 presents an example in which a number of microcomputers are used to build up an audio equipment system.

[7] On condition that the ROM program burning step need not be performed.

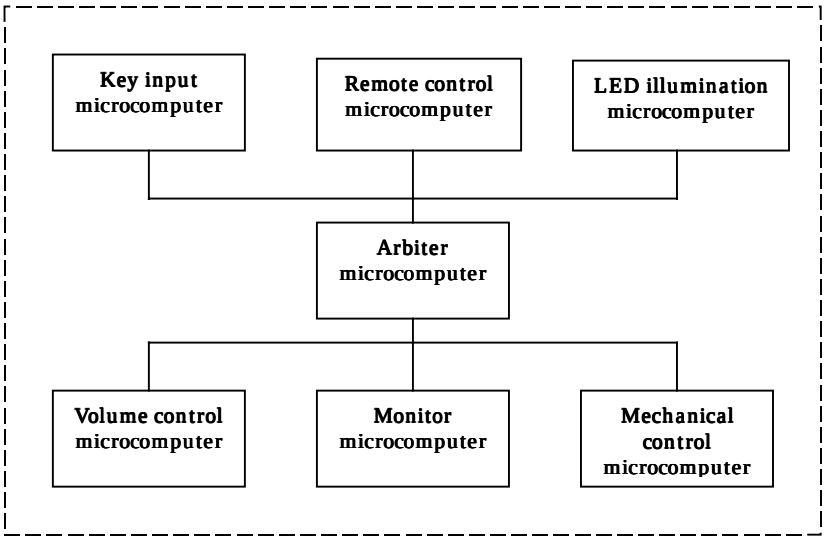


Figure 3.2 Microcomputer-based System Example(Audio Equipment)

Using independent microcomputers for various functions as indicated in the above example offers the following advantages.

1. **Individual programs are small so that program development is easy.**
2. **It is very easy to use previously developed software.**[8]
3. **Completely independent programs are provided for various functions so that program development can easily be conducted by a number of engineers.**

On the other hand, there are the following disadvantages.

1. **The number of parts used increases, thereby raising the product cost.**
2. **Hardware design is complicated.**
3. **Product physical size is enlarged.**

Therefore, if you employ the real-time OS in which a number of programs to be operatedby a number of microcomputers are placed under software control of one microcomputer, making it appear that the programs run on separate microcomputers, you can obviate all the above disadvantages while retaining the above-mentioned advantages.

Figure 3.3 shows an example system that will be obtained if the real-time OS is incorporated in the system indicated in Figure 3.2.

[8] In the case presented in Figure 3.2 for instance, the remote control microcomputer can be used for other products without being modified.

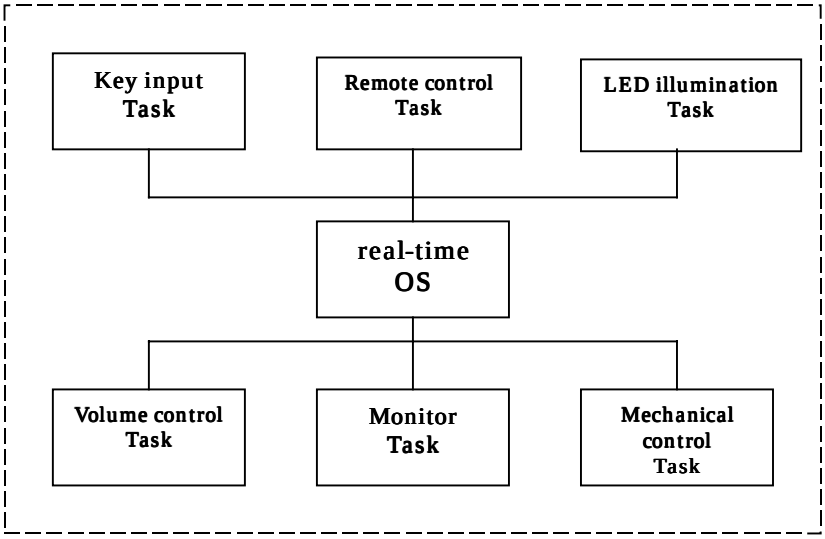


Figure 3.3 Example System Configuration with Real-time OS(Audio Equipment)

In other words, the real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers.

In the real-time OS, the individual programs, which correspond to a number of microcomputers used in a conventional system, are called tasks.

3.1.2 Operating Principles of Real-time OS

The real-time OS is the software that makes a one-microcomputer system look like operating a number of microcomputers. You should be wondering how the real-time OS makes a one-microcomputer system function like a number of microcomputers.

As shown in Figure 3.4 the real-time OS runs a number of tasks according to the time-division system. That is, it changes the task to execute at fixed time intervals so that a number of tasks appear to be executed simultaneously.

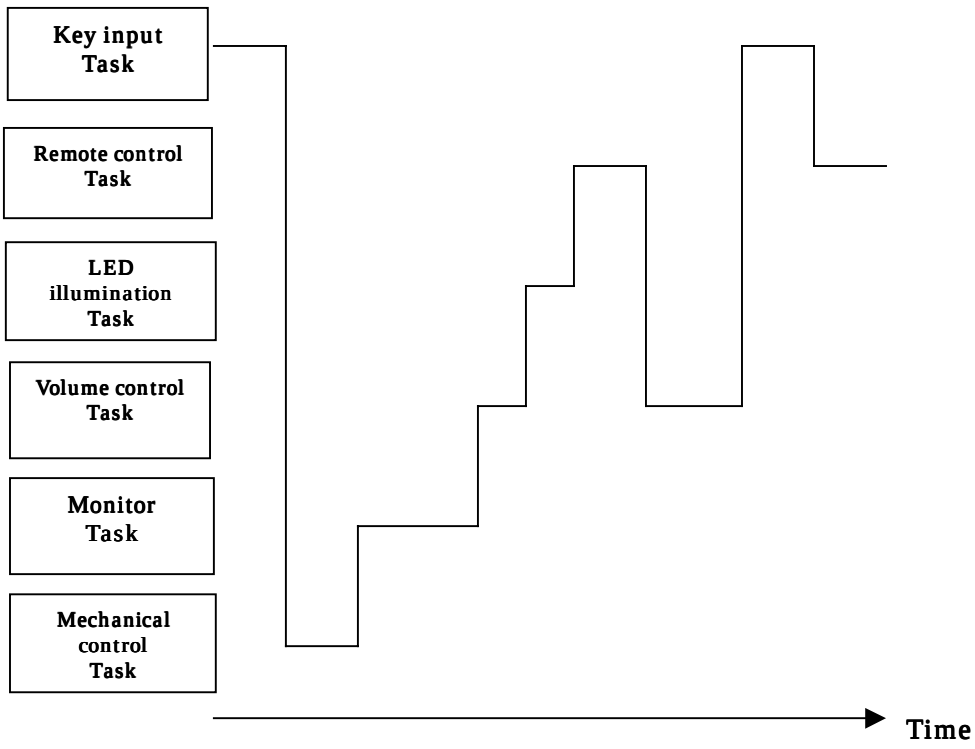


Figure 3.4 Time-division Task Operation

As indicated above, the real-time OS changes the task to execute at fixed time intervals. This task switching may also be referred to as dispatching (technical term specific to real-time operating systems). The factors causing task switching (dispatching) are as follows.

- Task switching occurs upon request from a task.
- Task switching occurs due to an external factor such as interrupt.

When a certain task is to be executed again upon task switching, the system resumes its execution at the point of last interruption (See Figure 3.5).

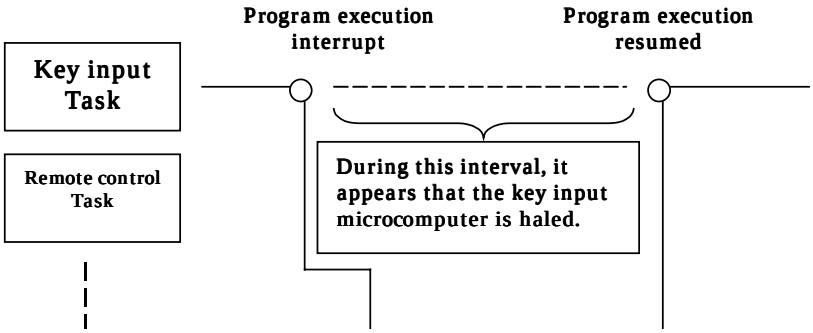

Program execution interrupt
Program execution resumed
Key input Task
Remote control Task
During this interval, it appears that the key input microcomputer is haled.

Figure 3.5 Task Execution Interruption and Resumption

In the state shown in Figure 3.5, it appears to the programmer that the key input task or its microcomputer is halted while another task assumes execution control.

Task execution restarts at the point of last interruption as the register contents prevailing at the time of the last interruption are recovered. In other words, task switching refers to the action performed to save the currently executed task register contents into the associated task management memory area and recover the register contents for the task to switch to.

To establish the real-time OS, therefore, it is only necessary to manage the register for each task and change the register contents upon each task switching so that it looks as if a number of microcomputers exist (See Figure 3.6).

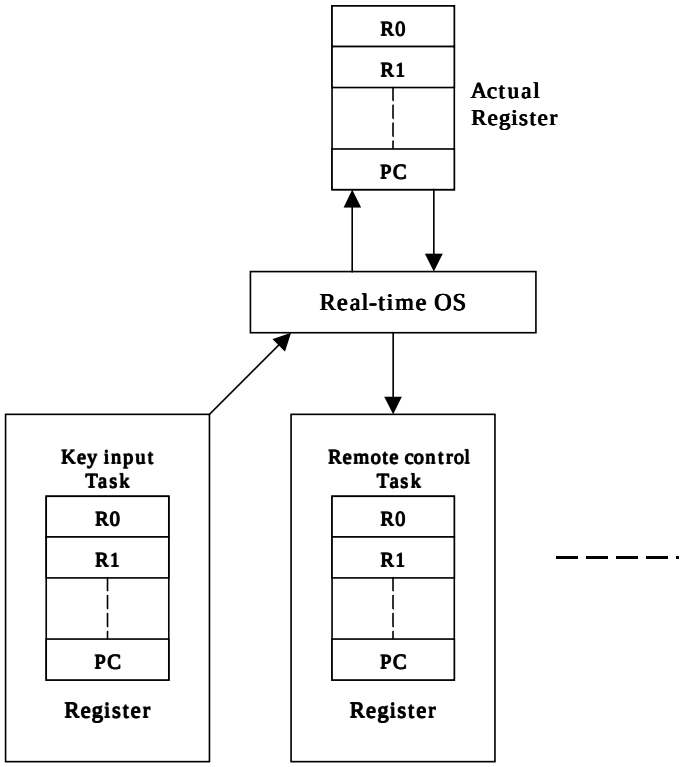


Figure 3.6 Task Switching

The example presented in Figure 3.1 indicates how the individual task registers are managed. In reality, it is necessary to provide not only a register but also a stack area for each task.

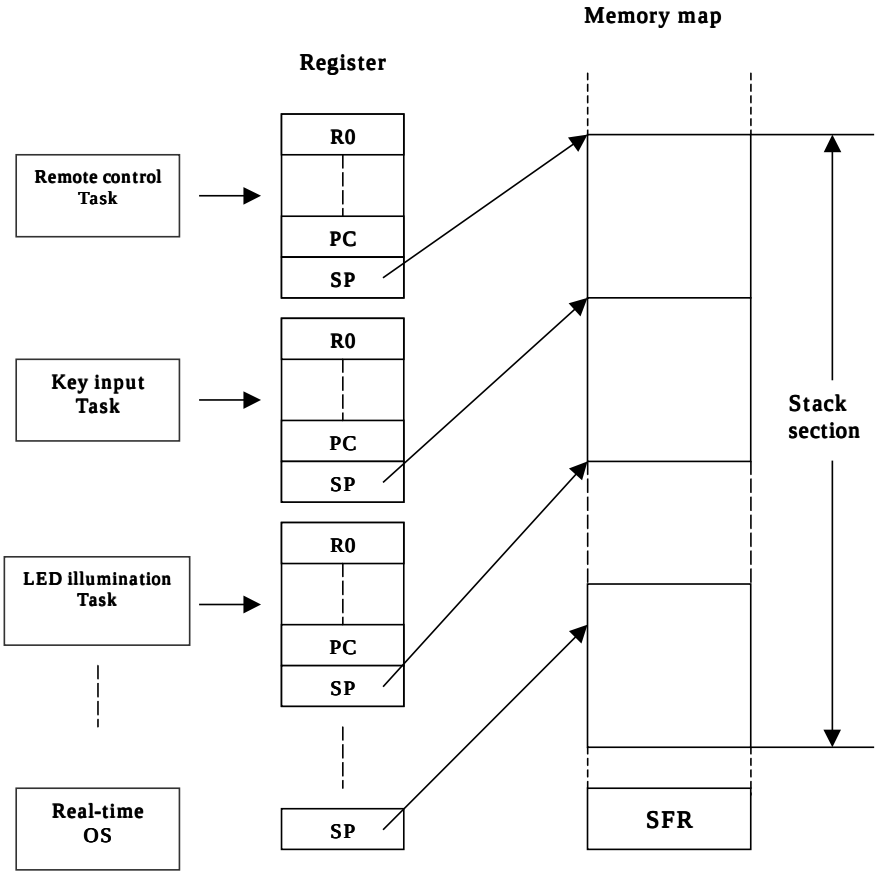


Figure 3.7 Task Register Area

Figure 3.8 shows the register and stack area of one task in detail. In the MR30, the register of each task is stored in a stack area as shown in Figure 3.8. This figure shows the state prevailing after register storage.

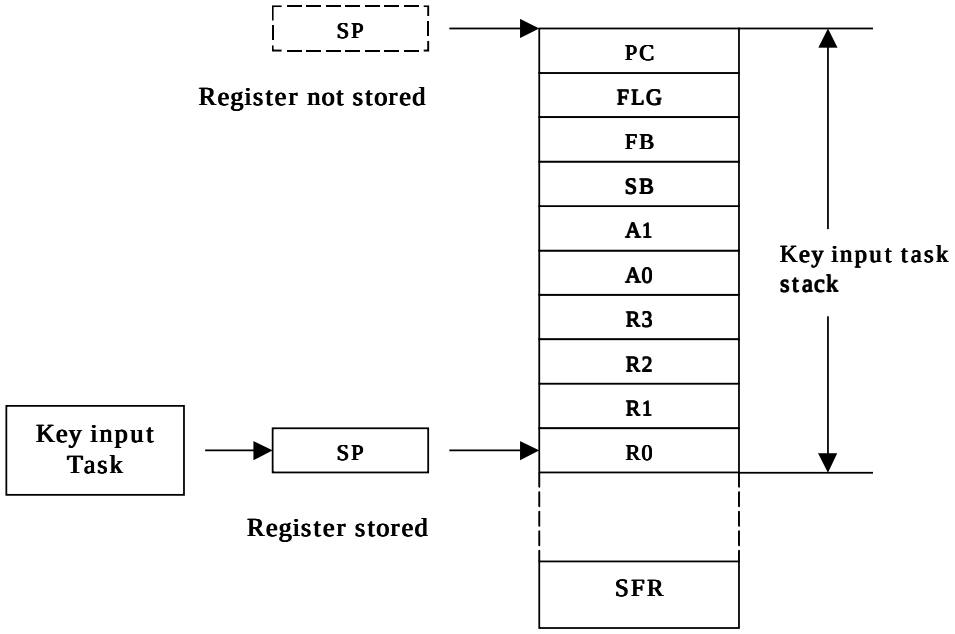


Figure 3.8 Actual Register and Stack Area Management

3.2 System Call

How does the programmer use the real-time OS in a program?

First, it is necessary to call up a real-time OS function from the program in some way or other. Calling a real-time OS function is referred to as a system call. Task activation and other processing operations can be initiated by such a system call (See Figure 3.9).

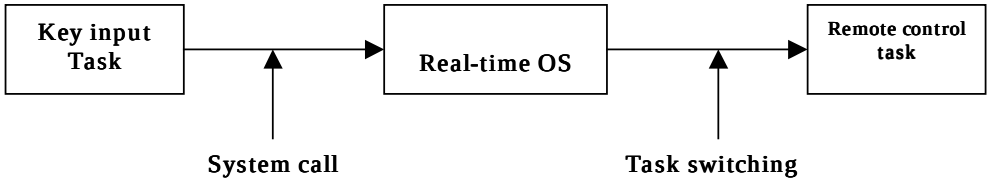


Figure 3.9 System Call

When application programs are to be written in C language, a system call is accomplished by making a function call, as indicated below.

```
sta_tsk(ID_main,3);
```

If application programs are to be written in assembly language, a system call is accomplished by making an assembler macro call, as indicated below.

```
sta_tsk #ID_main,#3
```

3.2.1 System Call Processing

When a system call is issued, processing takes place in the following sequence.[9]

1. **The current register contents are saved.**
2. **The stack pointer is changed from the task type to the real-time OS (system) type.**
3. **Processing is performed in compliance with the request made by the system call.**
4. **The task to be executed next is selected.**
5. **The stack pointer is changed to the task type.**
6. **The register contents are recovered to resume task execution.**

The flowchart in Figure 3.10 shows the process between system call generation and task switching.

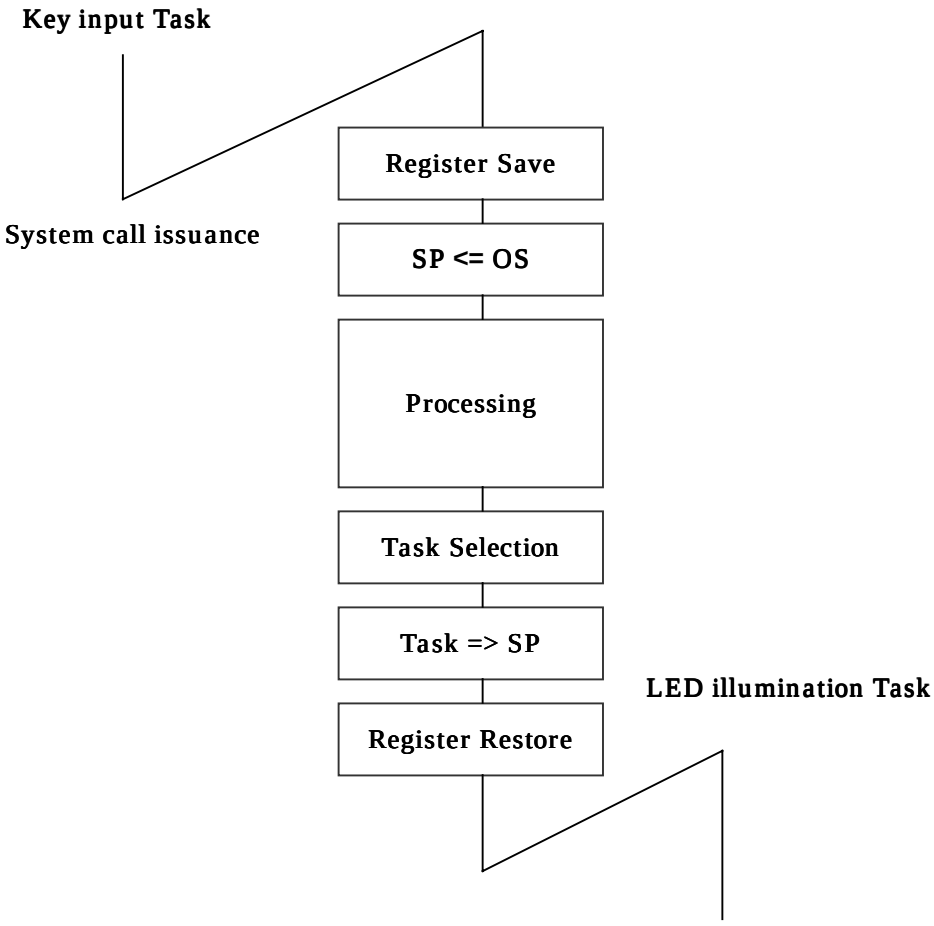


Figure 3.10 System Call Processing Flowchart

[9] A different sequence is followed if the issued system call does not evoke task switching.

3.2.2 Task Designation in System Call

Within the MR30 real-time OS, each task is identified by ID number.

For example, the system says, "Start the task having the task ID number 1."

However, if a task number is directly written in a program, the resultant program would be very low in readability. If, for instance, the following is entered in a program, the programmer is constantly required to know what the No. 2 task is.

```
sta_tsk(2,1);
```

Further, if this program is viewed by another person, he/she does not understand at a glance what the No. 2 task is. To avoid such inconvenience, the MR30 provides means of specifying the task by name (function or symbol name).

The program named "configurator cfg30 ,"which is supplied with the MR30, then automatically converts the task name to the task ID number. This task identification system is schematized in Figure 3.11.

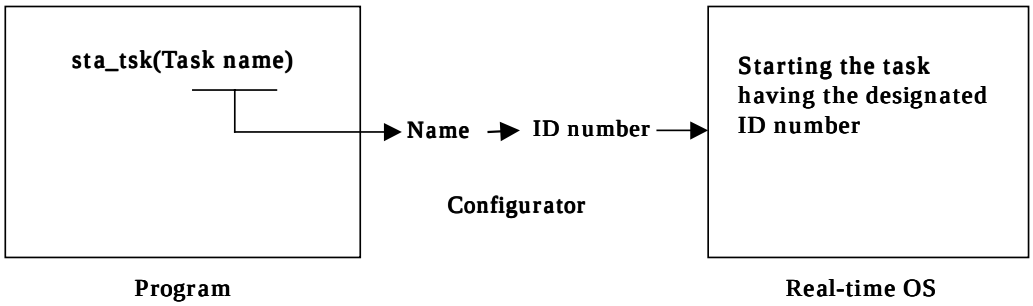


Figure 3.11 Task Identification

```
sta_tsk(ID_task,1);
```

In the above example, the system is instructed to start the task having the function name "task()" or the symbol name "task:".

It should also be noted that task name-to-ID number conversion is effected at the time of program generation. Therefore, the processing speed does not decrease due to this conversion feature.

3.3 Task

This chapter explains how the real-time OS controls the tasks.

3.3.1 Task Status

The real-time OS monitors the task status to determine whether or not to execute the tasks.

Figure 3.12 shows the relationship between key input task execution control and task status. When there is a key input, the key input task must be executed. That is, the key input task is placed in the execution (RUN) state. While the system waits for key input, task execution is not needed. In that situation, the key input task in the WAIT state.

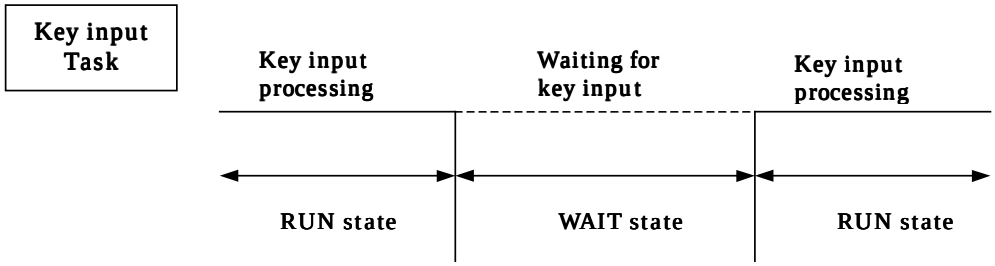


Figure 3.12 Task Status

The MR30 controls the following six different states including the RUN and WAIT states.

1. **RUN state**
2. **READY state**
3. **WAIT state**
4. **SUSPEND state**
5. **WAIT-SUSPEND state**
6. **DORMANT state**

Every task is in one of the above six different states. Figure 3.13 shows task status transition.

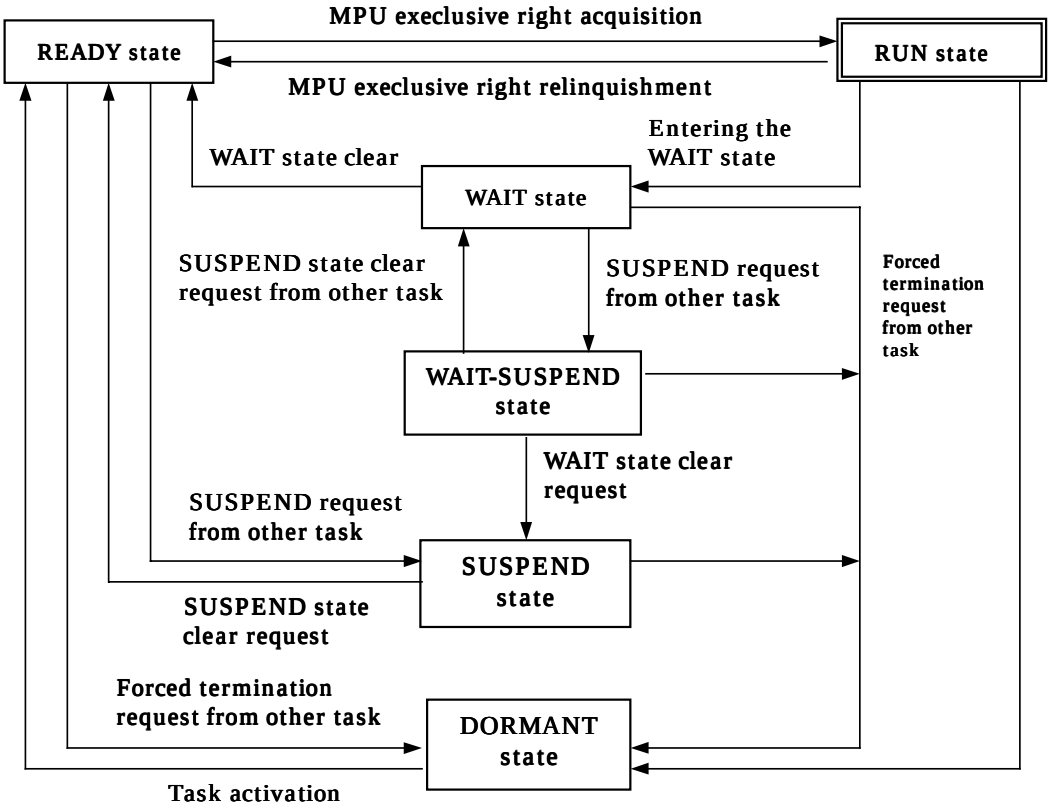


Figure 3.13 MR30 Task Status Transition

1. RUN state

In this state, the task is being executed. Since only one microcomputer is used, it is natural that only one task is being executed.

The currently executed task changes into a different state when any of the following conditions occurs.

- The task has normally terminated itself.[10]
- The task has placed itself in the WAIT state.[11]
- Due to interruption or other event occurrence, the interrupt handler has placed a different task having a higher priority in the READY state.
- The priority assigned to the task has been changed so that the priority of another READY task is rendered higher.[12]
- Due to interruption or other event occurrence, the priority of the task or a different READY task has been changed so that the priority of the different task is rendered higher.[13]

When any of the above conditions occurs, rescheduling takes place so that the task having the highest priority among those in the RUN or READY state is placed in the RUN state, and the execution of that task starts.

[10] Upon ext_tsk system call
[11] Upon slp_tsk, tslp_tsk, dly_tsk, wai_flg, twai_flg, wai_sem, twai_sem, rcv_msg or trcv_msg system call.
[12] Upon chg_pri system call.
[13] Upon ichg_pri system call.

2. READY state

The READY state refers to the situation in which the task that meets the task execution conditions is still waiting for execution because a different task having a higher priority is currently being executed.

When any of the following conditions occurs, the READY task that can be executed second according to the ready queue [14] is placed in the RUN state.

- A currently executed task has normally terminated itself.[15]
- A currently executed task has placed itself in the WAIT state.[16]
- A currently executed task has changed its own priority so that the priority of a different READY task is rendered higher.[17]
- Due to interruption or other event occurrence, the priority of a currently executed task has been changed so that the priority of a different READY task is rendered higher.[18]

3. WAIT state

When a task in the RUN state requests to be placed in the WAIT state, it exits the RUN state and enters the WAIT state. The WAIT state is usually used as the condition in which the completion of I/O device I/O operation or the processing of some other task is awaited.

The task goes into the WAIT state in one of the following ways.

- The task enters the WAIT state simply when the slp_tsk system call is issued.In this case, the task does not go into the READY state until its WAIT state is cleared explicitly by some other task.
- The task enters and remains in the WAIT state for a specified time period when the dly_tsk system call is issued. In this case, the task goes into the READY state when the specified time has elapsed or its WAIT state is cleared explicitly by some other task.
- When the wai_flg, wai_sem, or rcv_msg system call is issued, the task enters the WAIT state and waits to be requested. In this case, the task moves into the READY state when the request condition is met or its WAIT state is cleared explicitly by some other task.
- The tslp_tsk, twai_flg, twai_sem, and trcv_msg system calls specify the time-outs for the slp_tsk, wai_flg, wai_sem, and rcv_msg system calls. The system enters the wait state for the wait condition specified in each system call. After the wait condition is met or the specified time has elapsed, the task enters the executable state.
- When the task enters the WAIT state and waits to be requested upon the issuance of the wai_flg, twai_flg, wai_sem, twai_sem, rcv_msg or trcv_msg system call, it joins any of the following queues depending on the request.

- **Eventflag Queue**
- **Semaphore Queue**
- **Mailbox Queue**

4. SUSPEND state

When the sus_tsk system call is issued from a task in the RUN state or the isus_tsk system call is issued from a handler, the READY task designated by the system call or the currently executed task enters the SUSPEND state. If a task in the WAIT state is placed in this situation, it goes into the WAIT-SUSPEND state.

[14] For the information on the ready queue,see the next chapter.
[15] Upon ext_tsk system call.
[16] Upon slp_tsk,tslp_tsk,dly_tsk,wai_flg, twai_flg, wai_sem, twai_sem or rcv_msg system call.
[17] Upon chg_pri system call.
[18] Upon ichg_pri system call.

The SUSPEND state is the condition in which a READY task or currently executed task1[19] is excluded from scheduling to halt processing due to I/O or other error occurrence. That is, when the SUSPEND request is made to a READY task, that task is excluded from the execution queue.

Note that no queue is formed for the SUSPEND request. Therefore, the SUSPEND request can only be made to the tasks in the RUN, READY, or WAIT state.[20] If the SUSPEND request is made to a task in the SUSPEND state, an error code is returned.

5. WAIT-SUSPEND

When the SUSPEND request is made to a task in the WAIT state, that task goes into the WAIT-SUSPEND state. When the SUSPEND request is made to a task that is waiting for a request made by the wai_flg, twai_flg, wai_sem, twai_sem, rcv_msg or trcv_msg system call, that task remains in the request queue and simply goes into the WAIT- SUSPEND state.

When the wait condition for a task in the WAIT-SUSPEND state is cleared, that task goes into the SUSPEND state. It is conceivable that the wait condition may be cleared, when any of the following conditions occurs.

- The task wakes up upon wup_tsk, or iwup_tsk system call issuance.
- The task placed in the WAIT state by the dly_tsk or tslp_tsk system call wakes up after the specified time elapse.
- The request of the task placed in the WAIT state by the wai_flg , twai_flg, wai_sem, twai_sem, rcv_msg or trcv_msg system call is fulfilled.
- The WAIT state is forcibly cleared by the rel_wai or irel_wai system call

When the SUSPEND state clear request[21] is made to a task in the WAIT-SUSPEND state, that task goes into the WAIT state. Since a task in the SUSPEND state cannot request to be placed in the WAIT state, status change from SUSPEND to WAIT-SUSPEND does not possibly occur.

6. DORMANT

This state refers to the condition in which a task is registered in the MR30 system but not activated. This task state prevails when either of the following two conditions occurs.

- The task is waiting to be activated.
- The task is normally terminated[22] or forcibly terminated.[23]

[19] When a handler issued the isus_tsk system call to place a currently executed task in the SUSPEND state, status switching is effected directly from RUN to SUSPEND. This is exceptional status change and should be kept in mind.
[20] If the SUSPEND request is made to a task in the WAIT state, that task goes into the WAIT-SUSPEND state.
[21] rsm_tsk or irsm_tsk system call
[22] ext_tsk system call
[23] ter_tsk system call

3.3.2 Task Priority and Ready Queue

In the real-time OS, several tasks may simultaneously request to be executed. In such a case, it is necessary to determine which task the system should execute first.To properly handle this kind of situation, the system organizes the tasks into proper execution priority and starts execution with a task having the highest priority. To complete task execution quickly, tasks related to processing operations that need to be performed immediately should be given higher priorities.

The MR30 permits giving the same priority to several tasks. To provide proper control over the READY task execution order, the system generates a task execution queue called "ready queue." The ready queue structure is shown in Figure 3.14[24] The ready queue is provided and controlled for each priority level. The first task in the ready queue having the highest priority is placed in the RUN state.[25]

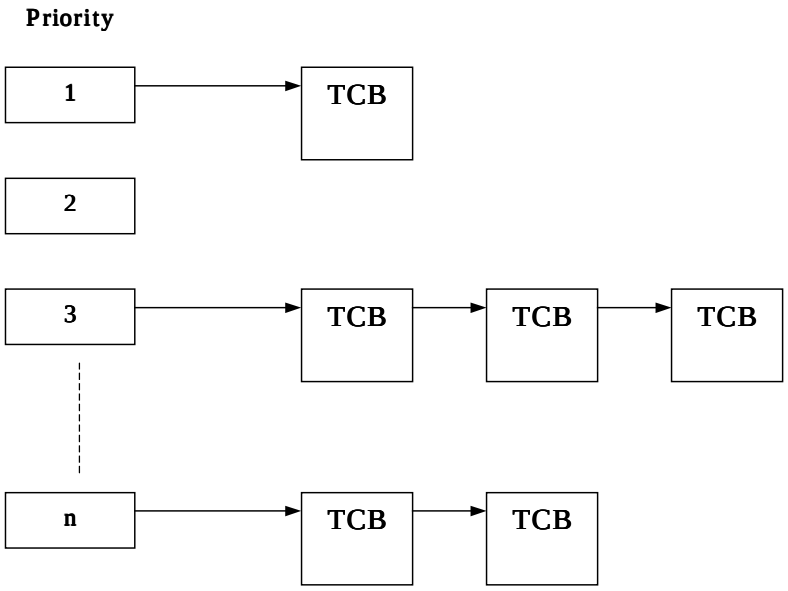


Figure 3.14 Ready Queue (Execution Queue)

[24] The TCB(task control block is described in the next chapter.)
[25] The task in the RUN state remains in the ready queue.

3.3.3 Task Control Block(TCB)

The task control block (TCB) refers to the data block that the real-time OS uses for individual task status, priority, and other control purposes.

The MR30 manages the following task information as the task control block

- Task connection pointer
  Task connection pointer used for ready queue formation or other purposes.
- Task status
- Task priority
- Task register information and other data[26] storage stack area pointer(current SP register value)
- Wake-up counter
  Task wake-up request storage area.
- Time-out counter or wait flag pattern
  When a task is in a time-out wait state, the remaining wait time is stored; if in a flag wait state, the flag's wait pattern is stored in this area.
- Flag wait mode
  This is a wait mode during eventflag wait.
- Timer queue connection pointer
  This area is used when using the timeout function. This area stores the task connection pointer used when constructing the timer queue.
- Flag wait pattern
  This area is used when using the timeout function.

  This area stores the flag wait pattern when using the eventflag wait system call with the time-out function (twai_flg). No flag wait pattern area is allocated when the eventflag is not used.

The task control block is schematized in Figure 3.15.

[26] Called the task context

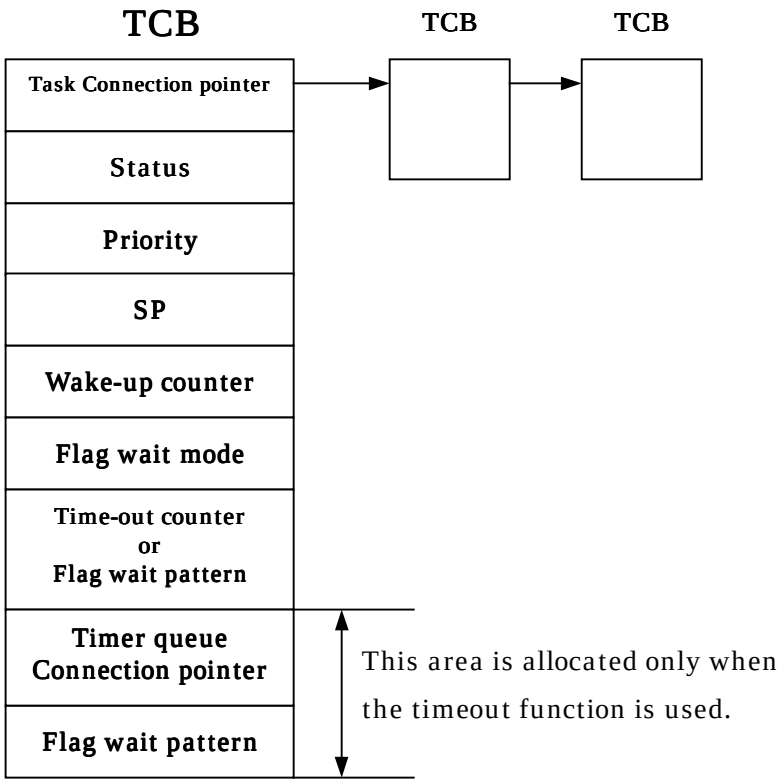


Figure 3.15 Task control block

3.4 Handler

3.4.1 Difference between Tasks and Handlers

The tasks are program units that the MR30 executes and controls. Each task has its own independent context (program counter, stack pointer, status register, and other registers).

Therefore, to transfer execution from one task to another[27] , it is necessary to effect context switching. This processing operation takes time.

Interrupt processing, which requires high-speed response, can be carried out by the MR30 without effecting context switching. That is, the interrupted task context (registers) can be used as is to run a program. This type of program is called the handler. As the handler uses the interrupted task context (registers) as is, it is always necessary to save the interrupted task context into memory at the beginning of the handler, and put the saved context back into the original position when returning to the task. To make a return from the interrupt handler, the ret_int system call should normally be used when written in assembly language.(See 5.2.2) However, if no MR30 system call is used within the interrupt handler, the reit instruction can be used to make a return.(See 5.2.3)

The following handlers are provided.

1. Interrupt Handler

A program that starts upon hardware interruption is called the interrupt handler. The MR30 is not concerned in interrupt handler activation. Therefore, the interrupt handler entry address is to be directly written into the interrupt vector table.

The interrupt handler is provided for two types of interrupts: OS-independent and OS-dependent interrupts. Refer to Section 5.5 for details about each interrupt.

2. Cyclic Handler

This handler is a program that starts cyclically at preselected time intervals. The cyclic handler activity is to be changed[28] determine whether or not to validate a preset cyclic handler.

3. Alarm Handler

This handler starts at preselected times.

If a system time is reset (etc. set_tim () system call) to a tme before an Alarm Handler already started, the Alarm Handler will never restart. If the system time is reset to a time after an Alarm Handler starts, all Alarm Handler will never start.

The cyclic handler and alarm handler are called up by means of a subroutine call from the system clock interrupt (timer interrupt) handler (See Figure 3.16). Therefore, the cyclic handler and alarm handler function as part of the system clock interrupt handler. Note that the cyclic handler and alarm handler are called up under the conditions whose state is the system clock interrupt priority level.

[27] This transfer is called dispatching or switching
[28] act_cyc system call

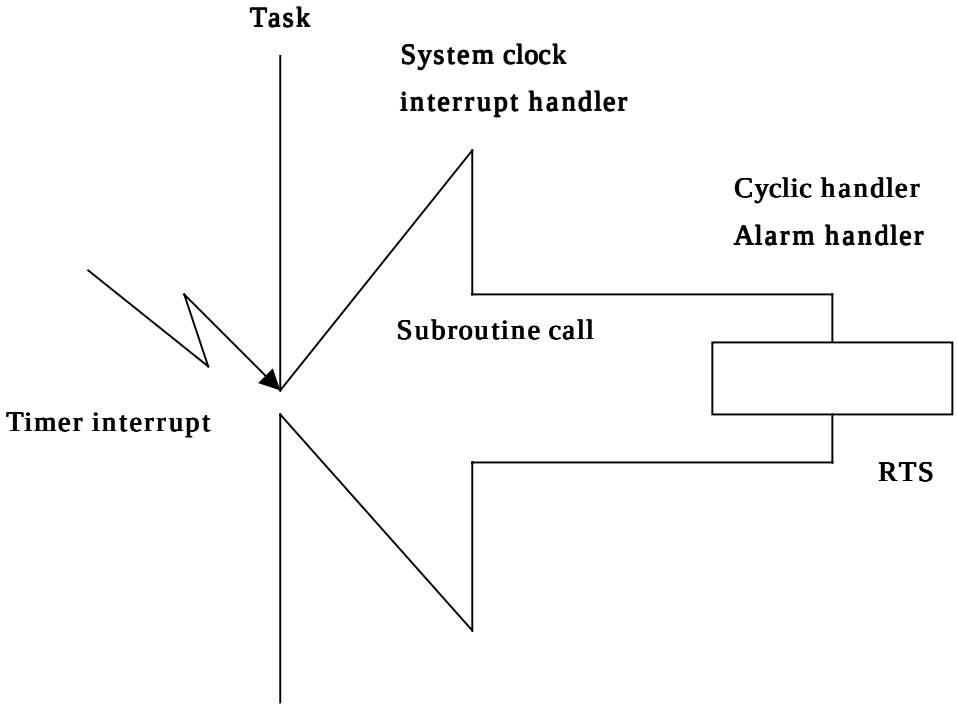


Figure 3.16 Cyclic Handler/Alarm Handler Activation

3.4.2 System Calls Exclusive for Handlers

In the MR30, the following system calls can be issued from the handlers only. Note, however, that the ret_int system call is dedicated to the interrupt handler[29] and therefore cannot be issued from the cyclic handler or alarm handler.

Table 3.1 System Calls Issuable from only Handlers

System call name		Function
ichg_pri	Change Task Priority	Changes the task priority.
irot_rdq	Rotate Ready Queue	Rotates the task ready queue.
irel_wai	Release Task Wait	Forcibly clears the task WAIT state.
isus_tsk	Suspend Task	Puts a task into the SUSPEND state.
irsm_tsk	Resume Task	Resumes the suspended task.
iwup_tsk	Wakeup Task	Wakes up the waiting task.
iset_flg	Set EventFlag	Sets an eventflag.
isig_sem	Signal Semaphore	Signal operation for a semaphore.
isnd_msg	Send Message to Mailbox	Sends a message.
ista_tsk	Start Task	Starts the task.
ret_int	Return from Interrupt Handler	Return from the interrupt handler.

[29] It isn't necessary to write this system call when specifying the interrupt handler as #pragma INTHANDLER in C language.

3.5 MR30 Kernel Structure

3.5.1 Module Structure

The MR30 kernel consists of the modules shown in Figure 3.17. Each of these modules is composed of functions that exercise individual module features.

The MR30 kernel is supplied in the form of a library, and only necessary features are linked at the time of system generation. More specifically, only the functions used are chosen from those which comprise these modules and linked by means of the Linkage Editor LN30. However, the scheduler module, part of the task management module, and part of the time management module are linked at all times because they are essential feature functions.

The applications program is a program created by the user. It consists of tasks, interrupt handler, alarm handler, and cyclic handler.[30]

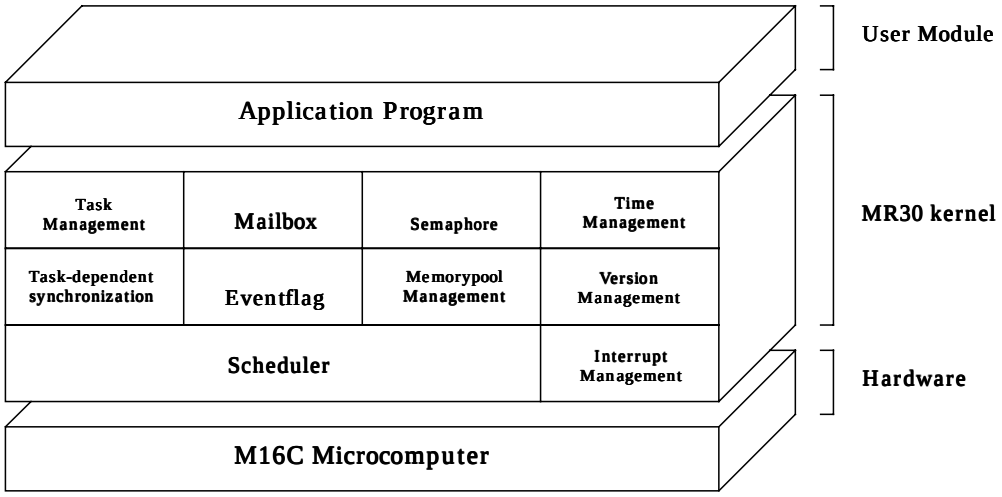


Figure 3.17 MR30 Structure

[30] For details, See 3.5.10.

3.5.2 Module Overview

The MR30 kernel modules are outlined below.

- **Scheduler**
  Forms a task processing queue based on task priority and controls operation so that the high-priority task at the beginning in that queue (task with small priority value) is executed.

- **Task Management Module**
  Exercises the management of various task states such as the RUN, READY, WAIT, and SUSPEND state.

- **Task Synchronization Module**
  Accomplishes inter-task synchronization by changing the task status from a different task.

- **Interrupt Management Module**
  Makes a return from the interrupt handler.

- **Time Management Module**
  Sets up the system timer used by the MR30 kernel and starts the user-created alarm handler[31] and cyclic handler.[32].

- **Version Management Module**
  Reports the MR30 kernel version number or other information.

- **Sync/Communication Module**
  This is the function for synchronization and communication among the tasks. The following three functional modules are offered.

  - Eventflag

    Checks whether the flag controlled within the MR30 is set up and then determines whether or not to initiate task execution. This results in accomplishing synchronization between tasks.

  - Semaphore

    Reads the semaphore counter value controlled within the MR30 and then determines whether or not to initiate task execution. This also results in accomplishing synchronization between tasks.

  - Mailbox

    Provides inter-task data communication by delivering the first data address.

- **Memorypool Management Module**
  Provides dynamic allocation or release of a memory area used by a task or a handler.

[31] This handler actuates once only at preselected times.
[32] This handler periodically actuates.

3.5.3 Task Management Function

The task management function is used to perform task operations such as task start/stop and task priority updating. The MR30 kernel offers the following task management function system calls.

- Starting the Task (sta_tsk)
  Starts the task, changing its status from DORMANT to either READY or RUN.

- Starting the Task from the handler (ista_tsk)
  By activating a task from the handler, the status of the task to be activated is changed from the DORMANT state to either READY or RUN.

- Ending Its Own Task (ext_tsk)
  Ends its own task and places it in the DORMANT state, so that this task will not be executed until activated again.

- Forcibly Terminating Some Other Task (ter_tsk)
  Forcibly terminates a different task placed in a state other than DORMANT and places it in the DORMANT state.

  When the forcibly terminated task is activated again, it acts as if it is reset (See Figure 3.18).

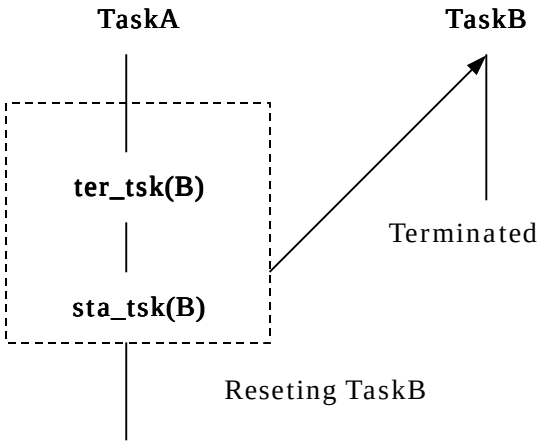


Figure 3.18 Task Resetting

- Changing the Task Priority (chg_pri, ichg_pri)
  Changes the task priority, and if the task is in the READY or RUN state, updates the ready queue also (See Figure 3.19).

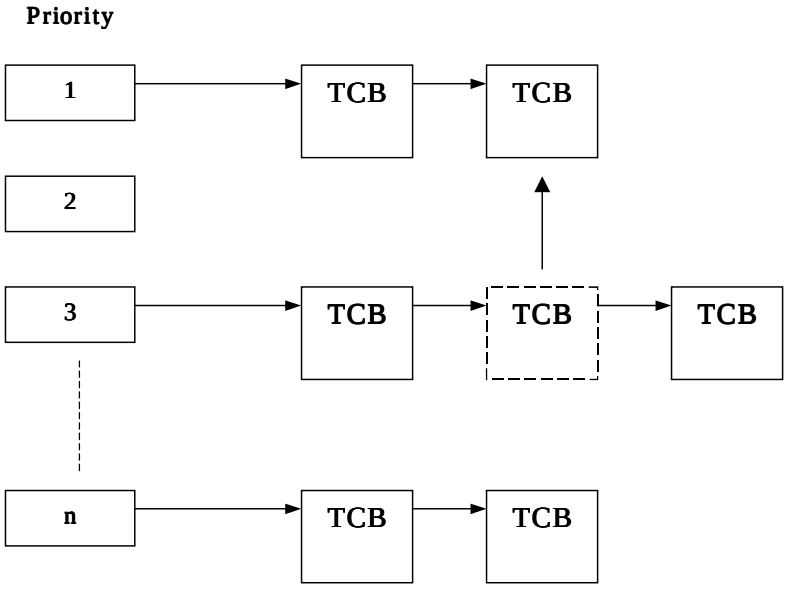


Figure 3.19 Priority Change

- Rotating the Ready Queue (rot_rdq, irot_rdq)
  This system call establishes the TSS (time-sharing system). That is, if the ready queue is rotated at regular intervals, round robin scheduling required for the TSS is accomplished (See Figure 3.20).

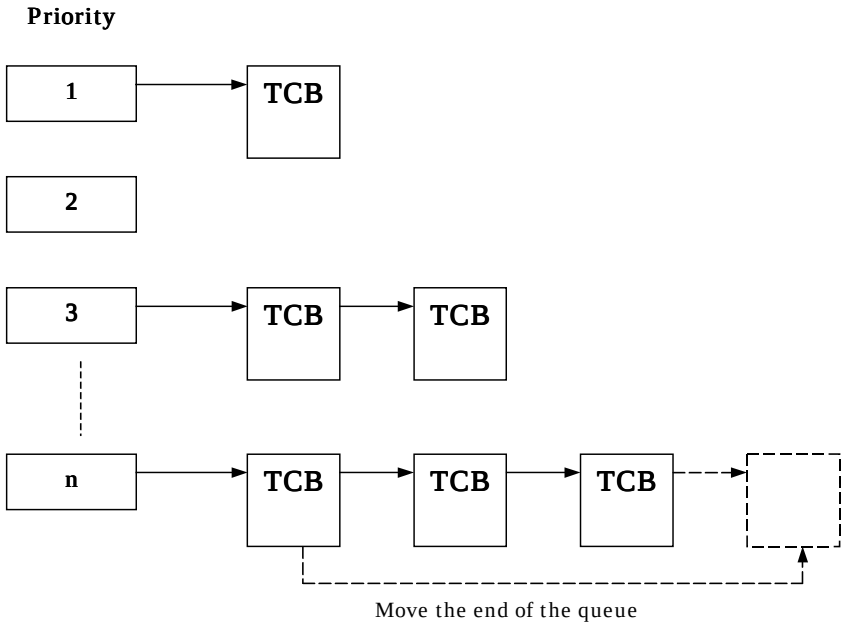


Figure 3.20 Ready Queue Management by rot_rdq System Call

- Forcibly Clearing the Task WAIT State (rel_wai, irel_wai)
  Forcibly clears the task WAIT state. The WAIT state tasks to be cleared by this system call are those which have entered the WAIT state under the following conditions.

- Waiting for timeout
- Waiting for by the slp_tsk system call(+With Timeout).
- Waiting for the eventflag(+With Timeout).
- Waiting for the semaphore(+With Timeout).
- Waiting for a message(+With Timeout).

- Acquiring Its Own ID (get_tid)
  Acquires its own task ID number. When this system call is issued from a handler, 0(zero) is obtained instead of the ID number.

- Refer Task Status (ref_tsk)
  Checks the status of the target task.

3.5.4 Synchronization functions attached to task

The task-dependent synchronization functions attached to task is used to accomplish synchronization between tasks by placing a task in the WAIT, SUSPEND, or WAIT-SUSPEND state or waking up a WAIT state task.

The MR30 offers the following task incorporated synchronization system calls.

- Placing a Task in the SUSPEND State (sus_tsk, isus_tsk)
- Restarting a Task Placed in SUSPEND State (rsm_tsk, irsm_tsk)
  Forcibly suspends or resumes task execution. If a READY task is forced to wait, it enters the SUSPEND state. If a WAITING state task is forcibly suspended, it enters the WAIT-SUSPEND state (See Figure 3.21).

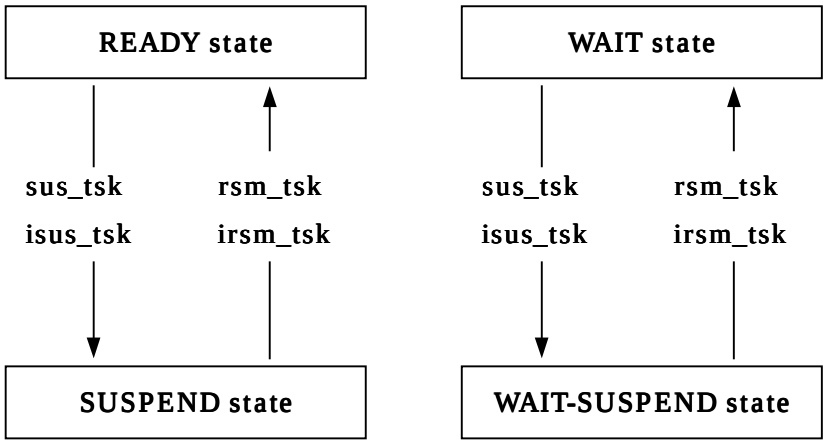


Figure 3.21 Suspending and Resuming a Task

- Placing a Task in the WAIT State (slp_tsk,tslp_tsk)
- Waking up wait state task (wup_tsk, iwup_tsk)
  Wakes up a task that has been placed in a WAIT state by the slp_tsk or tslp_tsk system call.

  No task can be waked up unless they have been placed in a WAIT state by.[33]

  If tasks that have been placed in a WAIT state for other conditions than the slp_tsk, tslp_tsk system call or tasks in other states except one that is in a DORMANT state are waked up by the iwup_tsk system call, it results in only wakeup requests being accumulated.

  Therefore, if a wakeup request is issued for a task in executing state, for example, that wake-up request is stored in memory temporarily. Then when the task in that executing state is placed in a wait state by the slp_tsk system call, the accumulated wakeup request becomes valid, so the task is executed continuously without being placed in a wait state. (See Figure 3.22).

[33] Tasks waiting under the following conditions will not be waked up.
- ♦ Waiting for the eventflag
- ♦ Waiting for the semaphore
- ♦ Waiting for the message
- ♦ Waiting for timeout

- Canceling a Task Wake-up Request (can_wup)
  Clears the stored wake-up reques.(See Figure 3.23).

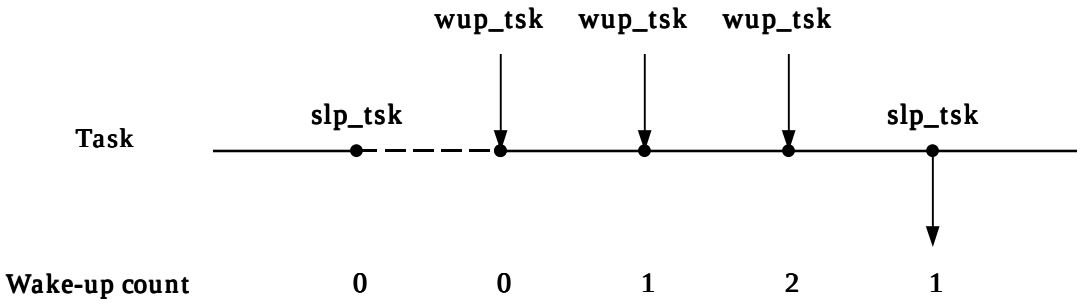


Figure 3.22 Wake-up Request Storage

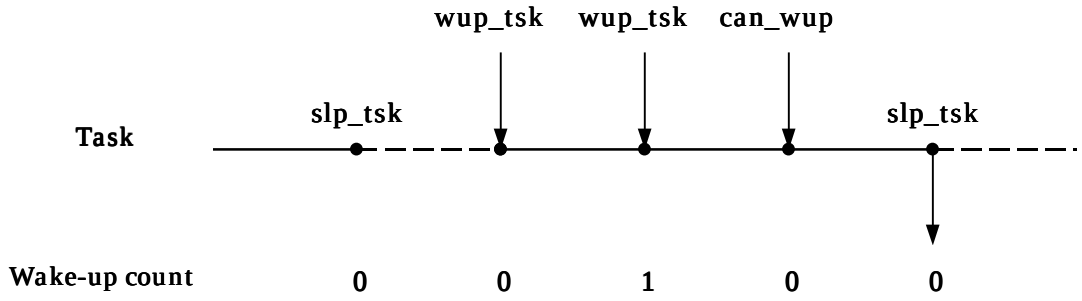


Figure 3.23 Wake-up Request Cancellation

3.5.5 Eventflag

The eventflag is an internal facility of MR30 that is used to synchronize the execution of multiple tasks. The eventflag uses a flag wait pattern and a 16-bit pattern to control task execution. A task is kept waiting until the flag wait conditions set are met.

The MR30 kernel offers the following eventflag system calls.

- Setting the Eventflag (set_flg, iset_flg)
  Sets the eventflag so that a task waiting the eventflag is released from the WAIT state.

- Clearing the Eventflag (clr_flg)
  Clearing the Eventflag.

- Waiting for eventflag (wai_flg, twai_flg)
  Waits until the eventflag is set to a certain pattern. There are three modes as listed below in which the eventflag is waited for.

  - AND wait
    Waits until all specified bits are set.
  - OR wait
    Waits until any one of the specified bits is set
  - Clear specification
    Clears the flag when the AND wait or OR wait condition is met.

- Getting eventflag (pol_flg)
  Examines whether the eventflag is in a certain pattern. In this system call, tasks are not placed in a wait state.

- Refer Eventflag Status (ref_flg)
  Checks the existence of the bit pattern and wait task for the target eventflag.

Figure 3.24 shows an example of task execution control by the eventflag using the wai_flg and set_flg system calls.

The eventflag has a feature that it can wake up multiple tasks collectively at a time.

In Figure 3.24, there are six tasks linked one to another, task A to task F. When the flag pattern is set to 0xF by the set_flg system call, the tasks that meet the wait conditions are removed sequentially from the top of the queue. In this diagram, the tasks that meet the wait conditions are task A, task C, task E, and task F. Out of these tasks, task A, task C, and task E are removed from the queue.

However, since task E is waiting in clear specification, the flag is cleared when task E is remove from the queue. Therefore, task F is not removed from the queue.

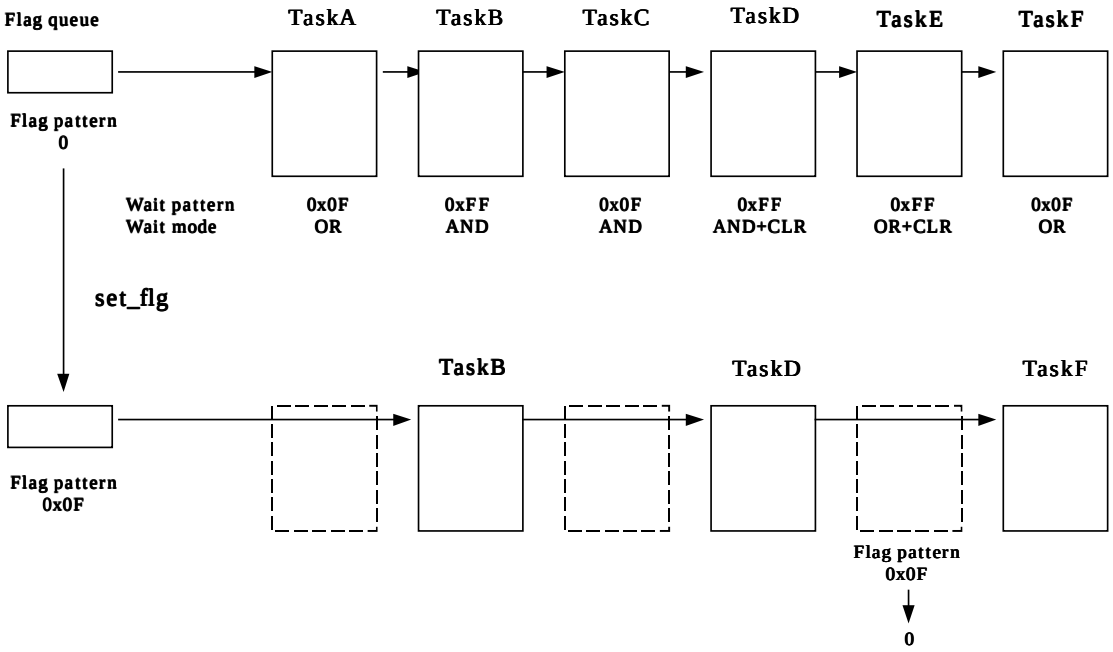


Figure 3.24 Task Execution Control by the Eventflag

3.5.6 Semaphore

The semaphore is a function executed to coordinate the use of devices and other resources to be shared by several tasks in cases where the tasks simultaneously require the use of them. When, for instance, four tasks simultaneously try to acquire a total of only three communication lines as shown in Figure 3.25, communication line-to-task connections can be made without incurring contention.

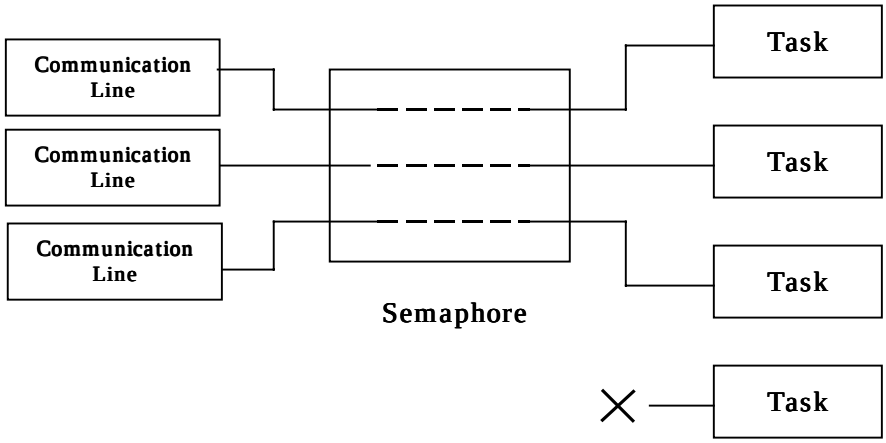


Figure 3.25 Exclusive Control by Semaphore

The semaphore has an internal semaphore counter. In accordance with this counter, the semaphore is acquired or released to prevent competition for use of the same resource.(See Figure 3.26).

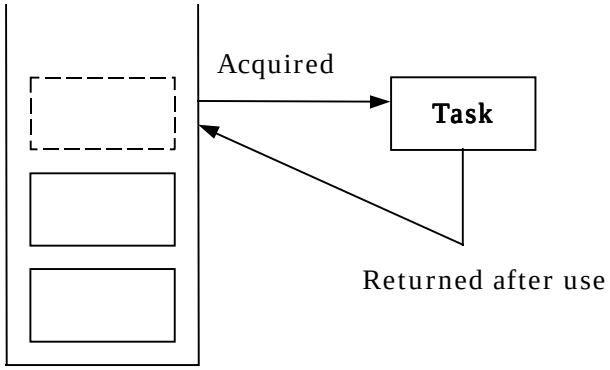


Figure 3.26 Semaphore Counter

The MR30 kernel offers the following semaphore synchronization system calls.

- Signaling the Semaphore (sig_sem, isig_sem)
  Sends a signal to the semaphore. This system call wakes up a task that is waiting for the semaphores service, or increments the semaphore counter by 1 if no task is waiting for the semaphores service.

- Acquiring the Semaphore (wai_sem, twai_sem)
  Waits for the semaphores service. If the semaphore counter value is 0 (zero), the semaphore cannot be acquired. Therefore, the WAIT state prevails.

- Acquiring the Semaphore (preq_sem)
  Acquires the semaphore. If there is no semaphore to acquire, an error code is returned and the WAIT state does not prevail.

- Refer Semaphore Status (ref_sem)
  Checks the status of the target semaphore. Checks the count value and existence of the wait task for the target semaphore.

  Figure 3.27 shows example task execution control provided by the wai_sem and sig_sem system calls.

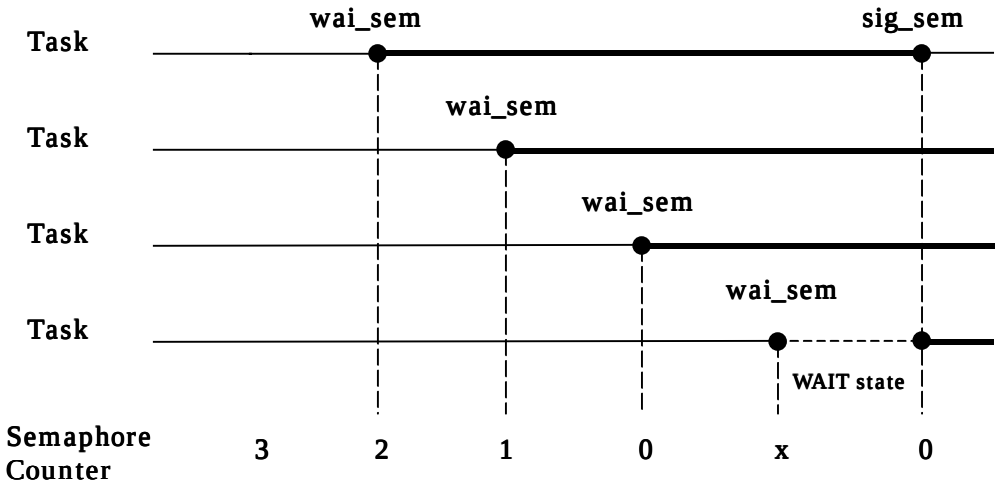


Figure 3.27 Task Execution Control by Semaphore

3.5.7 Mailbox

The mailbox is a mechanism that provides data communication between tasks. A typical example is presented in Figure 3.28. In this example, after task A sends a message in the mailbox, task B can obtain the message from the mailbox.

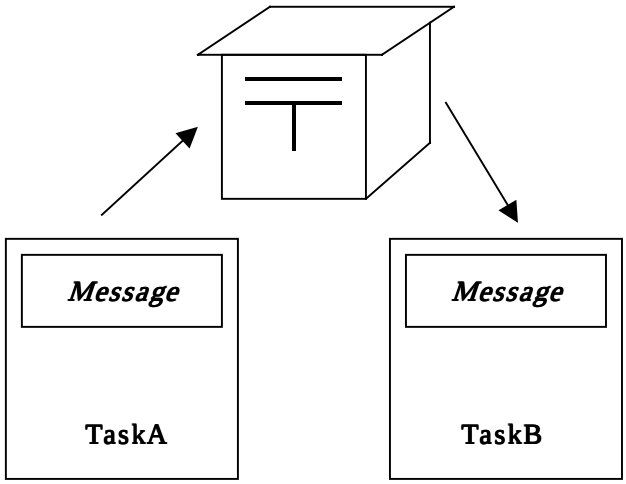


Figure 3.28 Mailbox

The messages that can be placed into this mailbox are 16-bit or 32-bit data. Standard specifications are such that MR30 uses this data as the start address of a message packet.[34] However, this data can be used simply as ordinary data.[35]

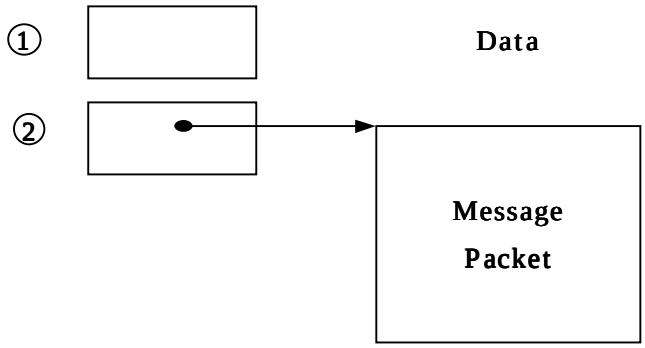


Figure 3.29 Meaning of Message

The mailbox is capable of storing messages. Stored messages are retrieved on the FIFO basis.[36]

However, the number of messages that can be stored in the mailbox is limited. The maximum number of messages that can be stored in the mailbox is referred to as the Message queue size (See Figure 3.30).

[34] According to the standard stated in ITRON Specification,this data is to be used as the message packet first address.
[35] In this case, Cast to the data of argument of the system call to convert into pointer types.
[36] First in, first out.

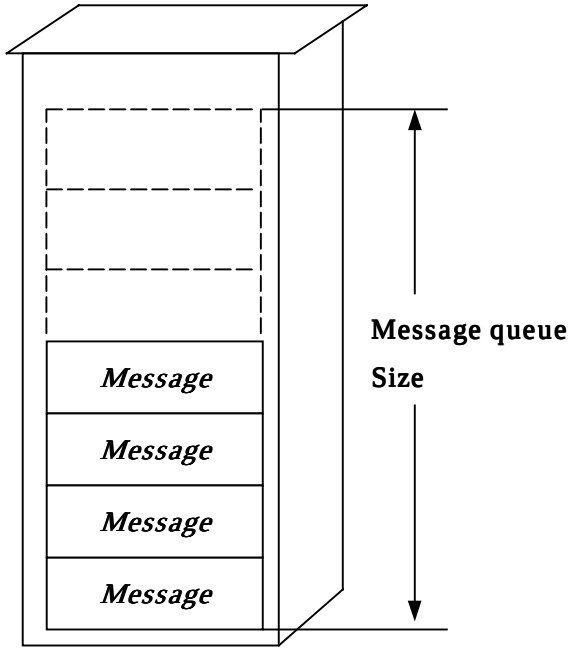


Figure 3.30 Message queue Size

The MR30 kernel offers the following mailbox system calls.

- Transmitting a Message (snd_msg, isnd_msg)
  Sends a message or puts a message into the mailbox.

- Receiving a Message (rcv_msg, trcv_msg)
  Receives a message or obtains a message from the mailbox. If the message is not in the mailbox, the WAIT state prevails until the message is put in the mailbox.

- Receiving a Message (prcv_msg)
  Receives a message. This system call differs from the rcv_msg system call in that the former returns an error code without incurring the WAIT state if the message is not found in the mailbox.

- Refer Mailbox Status (ref_mbx)
  Checks the existence of tasks waiting for messages to enter the target mailbox, and checks the first message in the mailbox.

3.5.8 Interrupt Management Function

The interrupt management function provides a function to process requested external interrupts in real time.

The interrupt management system calls provided by the MR30 kernel include the following:

- Returning from interrupt handler (ret_int)
  The ret_int system call activates the scheduler to switch over tasks as necessary when returning from the interrupt handler.

  When using the C language,[37], this function is automatically called at completion of the handler function. In this case, therefore, there is no need to invoke this system call.

- Disabling interrupts and task dispatch (loc_cpu)
  The loc_cpu system call disables OS-dependent external interrupts and task dispatch.

- Enabling interrupts and task dispatch (unl_cpu)
  The (unl_cpu) system call enables external interrupts and task dispatch. Therefore, this system call re-enables the interrupts and task dispatch that have been disabled by the loc_cpu system call.

Figure 3.31 shows an interrupt processing flow. Processing a series of operations from task selection to register restoration is called a "scheduler.".

[37] In the case that the interruput handler is specified by "#pragma INTHANDLER".

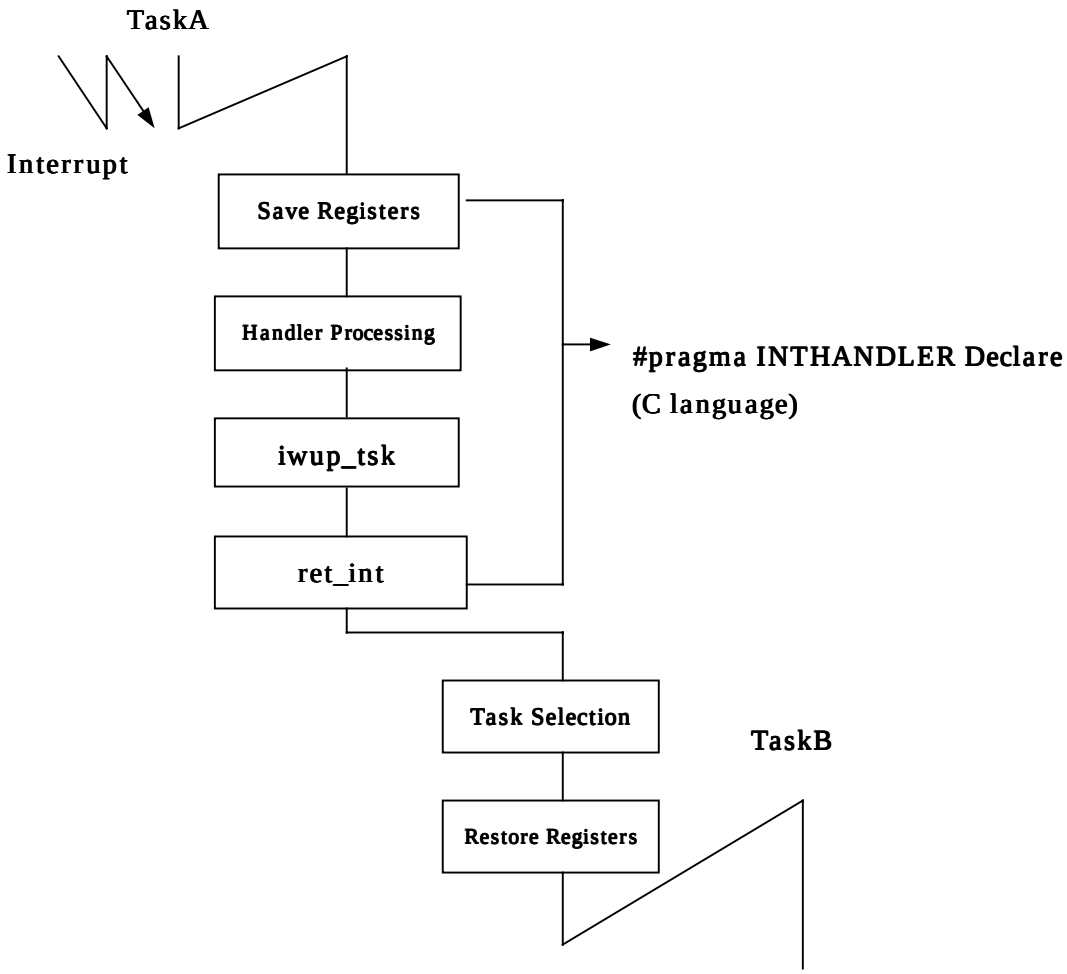


Figure 3.31 Interrupt process flow

3.5.9 Memorypool Management Function

The memorypool management function provides system memory space (RAM space) dynamic control.

This function is used to manage a specific memory area (memorypool), dynamically obtain memory blocks from the memorypool as needed for tasks or handlers, and release unnecessary memory blocks to the memorypool.

The MR30 supports two types of memorypool management functions, one for fixed-size and the other for variable-size.

Fixed-size Memorypool Management Function
You specify memory block size using configuration file.

The MR30 kernel offers the following Fixed-size memorypool management system calls.

- Acquiring a Memory Block (pget_blf)
- Releasing a Memory Block (rel_blf)

As shown in Figure 3.32, memory block 3 in the memorypool is passed to task C upon memory block acquisition request from task C. It is presumed in this case that memory blocks 1 and 2 are used by tasks A and B, respectively

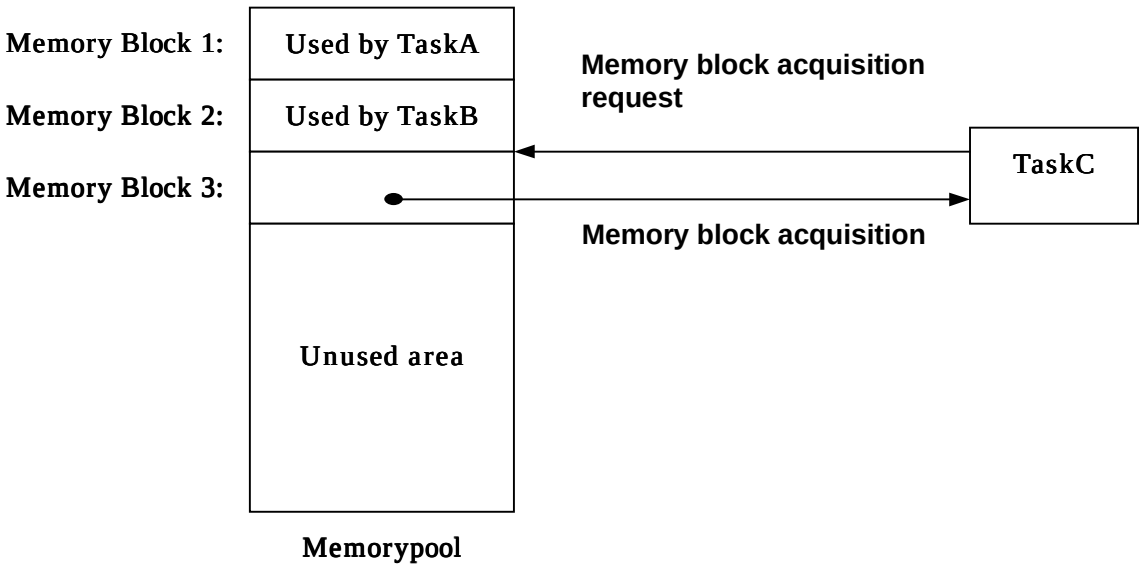


Figure 3.32 Memorypool Management

- Refer Memorypool Status (ref_mpf)
  Checks the number and size of free blocks in the target memorypool.

Variable-size Memorypool Management Function

The technique that allows you to arbitrary define the size of memory block acquirable from the memorypool is termed Variable-size scheme. The MR30 manages memory in terms of four fixed-size memory block sizes.

The MR30 calculates the size of individual blocks based on the maximum memory block size to be acquired. You specify the maximum memory block size using the configuration file.

```
e.g.
     variable_memorypool[]{
            max_memsize     = 400; <---- Maximum size
            heap_size       = 5000;
     };
```

Defining a variable-size memorypool as shown above causes four fixed-size memory block sizes to become 56 bytes, 112 bytes, 224 bytes, and 448 bytes in compliance with max_memsize.

In the case of user-requested memory, the MR30 performs calculations based on the specified size and selects and allocates the optimum one of four fixed-size memory block sizes. The MR30 cannot allocate a memory block that is not one of the four sizes.

System calls the MR30 provides include the following.

- Acquiring a memory block (pget_blk)

  Round off a block size you specify to the optimal block size among the four block sizes, and acquires memory having the rounded-off size from the memorypool.

  The following equations define the block sizes:

  $a = (((max\_memsize+(X-1))/ X \times 8)+1) \times 8$
  $b = a \times 2$
  $c = a \times 4$
  $d = a \times 8$

  max_memsize: the value specified in the configuration file
  X: data size for block control (8 byte)

  For example, if you request 200-byte, the MR30 rounds off the size to 244 bytes, and acquires 244-byte memory.

  If memory acquirement goes well, the MR30 returns the first address of the memory acquired along with the error code "E_OK". If memory acquirement fails, the MR30 returns the error code "E_TMOUT".

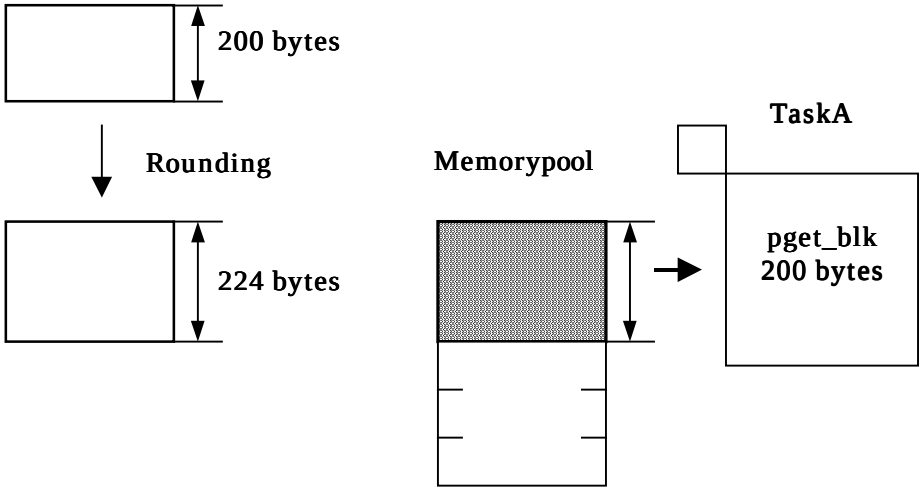


Figure 3.33 pget_blk processing

- Releasing a Memory block (rel_blk)
  Release a acquired memory block by pget_blk system call.

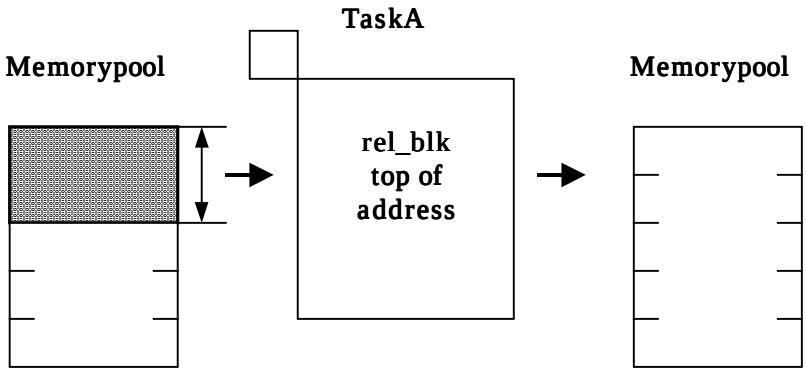


Figure 3.34 rel_blk processing

- Refer Memorypool Status (ref_mpl)
  Checks the total free area of the memorypool, and the size of the maximum free area that can immediately be acquired.

3.5.10 Time Management Function

The time management function provides system time management, time reading[38], time setup[39], and the functions of the alarm handler, which actuates at preselected times, and the cyclic handler, which actuates at preselected time intervals.

The MR30 kernel makes an exclusive use of one M16C/60 Series microcomputer hardware timer as the system timer. The configuration file is used to determine which timer is to be employed as the system timer.

The MR30 kernel offers the following time management system calls.

- Placing a task in wait state for certain time (dly_tsk)
  Keeps a task waiting for a certain time.Figure 3.35 shows an example in which task execution is kept waiting for 10 ms by the dly_tsk system call.

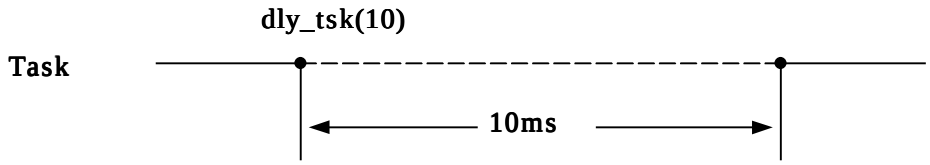


Figure 3.35 dly_tsk system call

- Specifying a timeout value in the wait state causes the MR30 to switch to a fixed wait-time status.
  You can specify a timeout in a system call for switching the task to the wait state.[40] The system calls are named tslp_tsk, twai_flg, twai_sem, and trcv_msg. If the conditions for exiting the wait state are not satisfied prior to the specified timeout time elapsing, error code E_TMOUT is returned and the wait state is cancelled. If the conditions for exiting the wait state are satisfied, error code E_OK is returned. (See Figure 3.36)

  The MR30 system clock is used as the reference time for the timeout.

[38] get_tim system call
[39] set_tim system call
[40] Cancel forced wait state.

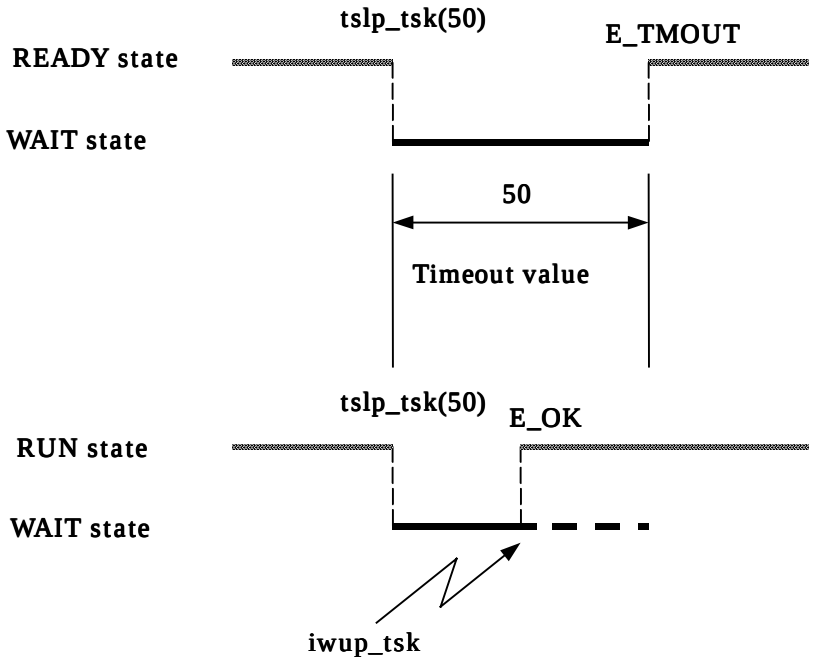


Figure 3.36 Timeout Processing

- Setting the System Time (set_tim)

- Reading the System Time (get_tim)
  The number of system clock interrupts generated after resetting is counted to indicate the system time in 48-bit data.

- Controlling the Cyclic Handler Activity (act_cyc)
  The cyclic handler is a program running at fixed time intervals (See Figure 3.37). It cyclically actuates according to the system clock interrupt count. For cyclic handler control purposes, its activity status is specified by the system call. For example, TCY_ON may be selected to change the activity status from OFF to ON (See Figure 3.38), or TCY_INI_ON may be selected to initialize the handler count (See Figure 3.39).

- Refer Cycle Start Handler Status (ref_cyc)
  Checks the activity of the target cycle handler and the time remaining till the next start.

- Refer Alarm Handler Status (ref_alm)
  Checks the time remaining till the target alarm handler is next started.

Note that the system timer function is not indispensable. Therefore, if the following system calls and the time management function are not to be used, there is no need to make an exclusive use of one timer for the MR30.

1. **System clock setup/reading** [41]
2. **Cyclic handler**
3. **Alarm handler**
4. **dly_tsk system call**
5. **system call with Timeout**

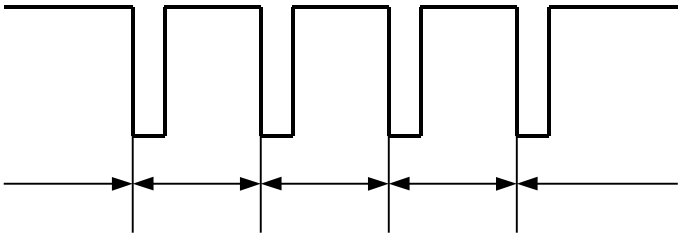


Figure 3.37 Cyclic Handler

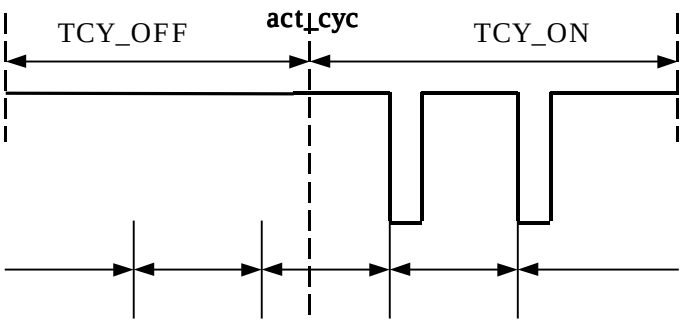


Figure 3.38 Cyclic Handler; TCY_ON Selected as Activity Status

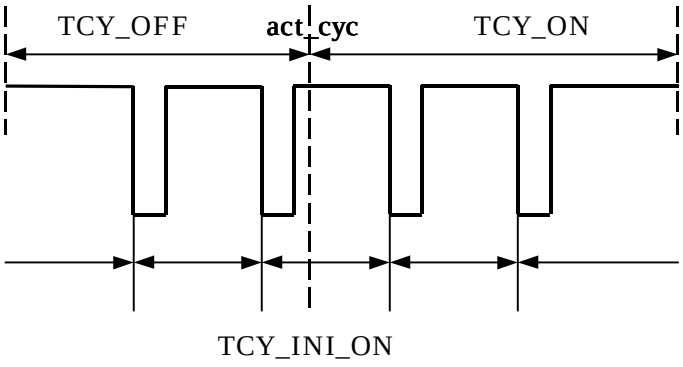


Figure 3.39 Cyclic Handler; TCY_INI_ON Selected as Activity Status

[41] set_tim, get_tim system call

3.5.11 Version Management Function

The information on the MR30 version can be obtained using the get_ver system call.

The version information is obtained in the format standardized in the TRON Specification. The get_ver system call furnishes the following information.

- **Manufacturer Name**
  Number indicating Renesas Corporation.

- **Type Number**
  Product identification number.

- **Specification Version**
  The number representing the µITRON Specification plus the version number of the µITRON Specification document on which the product is based.

- **Product Version**
  MR30 version number.

- **Product Control Information**
  Product release number, release date, and other associated data.

- **MPU Information**
  Number representing the M16C/80 Series Microcomputer.

- **Variation Descriptor**
  Number of the function set available for use with the MR30.

3.5.12 System Calls That Can Be Issued from Task and Handler

There are system calls that can be issued from a task and those that can be issued from a handler while there are other system calls that can be issued from both.

Table 3.2 lists those system calls.

Table 3.2 List of the system call can be issued from the task and handler

System Call	Task	Interrupt Handler	Cyclic Handler	Alarm Handler
sta_tsk	O	×	×	×
ista_tsk	×	O	O	O
ext_tsk	O	×	×	×
ter_tsk	O	×	×	×
dis_dsp	O	×	×	×
ena_dsp	O	×	×	×
chg_pri	O	×	×	×
ichg_pri	×	O	O	O
rot_rdq	O	×	×	×
irot_rdq	×	O	O	O
rel_wai	O	×	×	×
irel_wai	×	O	O	O
get_tid	O	O	O	O
ref_tsk	O	O	O	O
sus_tsk	O	×	×	×
isus_tsk	×	O	O	O
rsm_tsk	O	×	×	×
irsm_tsk	×	O	O	O
slp_tsk	O	×	×	×
tslp_tsk	O	×	×	×
dly_tsk	O	×	×	×
wup_tsk	O	×	×	×
iwup_tsk	×	O	O	O
can_wup	O	O	O	O
set_flg	O	×	×	×
iset_flg	×	O	O	O
clr_flg	O	O	O	O
wai_flg	O	×	×	×
twai_flg	O	×	×	×
pol_flg	O	O	O	O
ref_flg	O	O	O	O

System Call	Task	Interrupt Handler	Cyclic Handler	Alarm Handler
sig_sem	O	×	×	×
isig_sem	×	O	O	O
wai_sem	O	×	×	×
twai_sem	O	×	×	×
preq_sem	O	O	O	O
ref_sem	O	O	O	O
snd_msg	O	×	×	×
isnd_msg	×	O	O	O
rcv_msg	O	×	×	×
trcv_msg	O	×	×	×
prcv_msg	O	O	O	O
ref_mbx	O	O	O	O
pget_blf	O	O	O	O
rel_blf	O	O	O	O
ref_mpf	O	O	O	O
pget_blk	O	×	×	×
rel_blk	O	×	×	×
ref_mpl	O	O	O	O
ret_int	×	O[42]	×	×
loc_cpu	O	×	×	×
unl_cpu	O	×	×	×
set_tim	O	O	O	O
get_tim	O	O	O	O
act_cyc	O	O	O	O
ref_cyc	O	O	O	O
ref_alm	O	O	O	O
get_ver	O	O	O	O
vrst_msg	O	×	×	×
vrst_blf	O	×	×	×
vrst_blk	O	×	×	×

[42] The System Call can't be issued from the Interrupt Handler in C language.

Chapter 4 Applications Development Procedure Overview

4.1 General Description

The MR30 application programs are generally developed using the following procedures.

1. Applications Program Coding

Code application programs in C or assembly language. At this time, copy the sample startup program "crt0mr.a30" or "start.a30" from the directory indicated by the environment variable "LIB30" to the current directory.[43] Further, if necessary, modify the startup program and the section definition file.

2. Configuration File Preparation

Using the editor, prepare the configuration file in which the task entry address, stack size, and the like are defined.

3. Configurator Execution

Using the configuration file, create the system data definition files (sys_rom.inc and sys_ram.inc), include files (mr30.inc and id.h), and system generation procedure description file (makefile).

4. System Generation

Generate the system by executing the make[44] command.

5. Writing into ROM

Using the prepared ROM write form file, write the program into ROM, or allow the debugger to read the program to conduct debugging.

Figure 4.1 shows MR30 System Generation Detail Flowchart.

[43] The standard startup programs "crt0mr.a30" and "start.a30" are in the directory indicated by the environmentr variable "LIB30".
[44] The make command comes the UNIX standard and UNIX compatible.

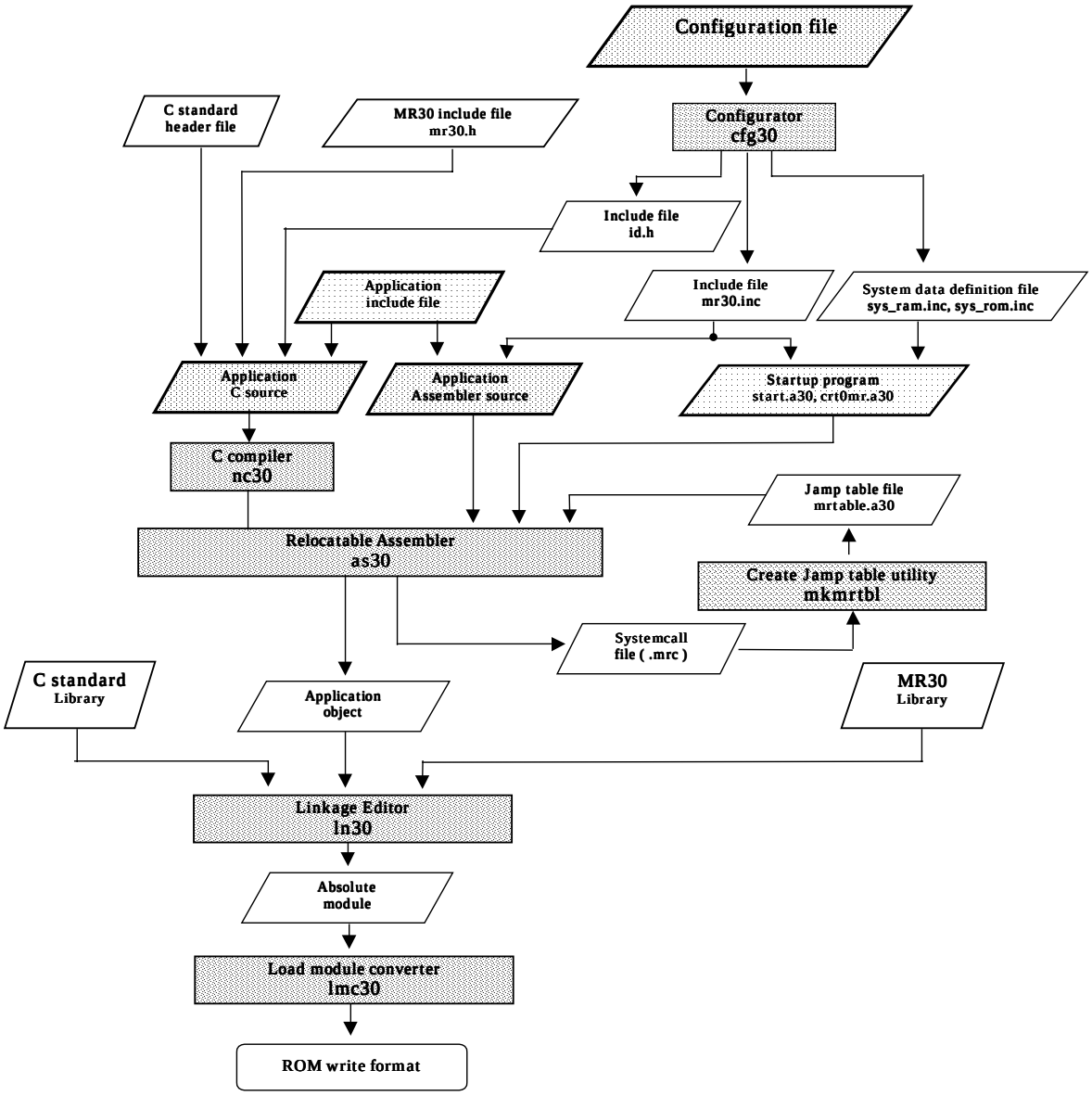


Figure 4.1 MR30 System Generation Detail Flowchart

4.2 Development Procedure Example

This chapter outlines the development procedures on the basis of a typical MR30 application example.

4.2.1 Applications Program Coding

Figure 4.2 shows a program that simulates laser beam printer operations. Let us assume that the file describing the laser beam printer simulation program is named lbp.c. This program consists of the following three tasks and one interrupt handler.

- Main Task
- Image expansion task
- Printer engine task
- Centronics interface interrupt handler

This program uses the following MR30 library functions.

- sta_tsk()
  Starts a task. Give the appropriate ID number as the argument to select the task to be activated. When the id.h file, which is generated by the configurator, is included, it is possible to specify the task by name (character string).[45]

- wai_flg()
  Waits until the eventflag is set up. In the example, this function is used to wait until one page of data is entered into the buffer via the Centronics interface.

- wup_tsk()
  Wakes up a specified task from the WAIT state. This function is used to start the printer engine task.

- slp_tsk()
  Causes a task in the RUN state to enter the WAIT state. In the example, this function is used to make the printer engine task wait for image expansion.

- iset_flg()
  Sets up the eventflag. In the example, this function is used to notify the image expansion task of the completion of one-page data input.

  At this time, make sure that the startup program "crt0mr.a30" and section definition file "c_sec.inc" are copied to the current directory. For example,

```
> copy %LIB30%\crt0mr.a30 .
> copy %LIB30%\c_sec.inc .
```

[45] The configurator converts the ID number to the associated name(character string) in accordance with the information entered int the configuration file.

```
#include <mr30.h>
#include "id.h"


void main() /* main task */
{
    printf("LBP start simulation \n");
    sta_tsk(ID_idle,1);     /* activate idle task */
    sta_tsk(ID_image,1);    /* activate image expansion task */
    sta_tsk(ID_printer,1);  /* activate printer engine task */
}
void image() /* activate image expansion task */
{
    while(1){
            wai_flg(&flgptn,ID_pagein,waiptn,TWF_ANDW+TWF_CLR);/* wait for 1-
page input */

            printf(" bit map expansion processing \n");
            wup_tsk(ID_printer);    /* wake up printer engine task */
    }
}
void printer() /* printer engine task */
{
    while(1){
            slp_tsk();
            printf(" printer engine operation \n");
    }
}
void sent_in() /* Centronics interface handler */
{


    /* Process input from Centronics interface */
    if ( /* 1-page input completed */ )
            iset_flg(ID_pagein,setptn);
}
```

Figure 4.2 Program Example

4.2.2 Configuration File Preparation

Prepare the configuration file in which the task entry address, stack size, and the like are defined. Figure 4.3 shows the configuration file (named "lbp.cfg") of the laser beam printer simulation program.

```
// System Definition
system{
    stack_size              = 1024;
    priority                = 5;
    system_IPL              = 4;
};
//System Clock Definition
clock{
    mpu_clock               = 20MHz;
    timer                   = A0;
    IPL                     = 4;
    unit_time               = 10ms;
    initial_time            = 0:0:0;
};
//Task Definition
task[1]{
    entry_address           = main();
    stack_size              = 512;
    priority                = 1;
    initial_start           = ON;
};
task[2]{
    entry_address           = image();
    stack_size              = 512;
    priority                = 2;
};
task[3]{
    entry_address           = printer();
    stack_size              = 512;
    priority                = 4;
};
task[4]{
    entry_address           = idle();
    stack_size              = 256;
    priority                = 5;
};
//Eventflag Definition
flag[1]{
     name                   = pagein;
};
//Interrupt Vector Definition
interrupt_vector[0x23]{
    os_int                  = YES;
    entry_address           = sent_in();
};
```

Figure 4.3 Configuration File Example

4.2.3 Configurator Execution

Execute the configurator cfg30 to generate the system data definition files (sys_rom.inc and sys_ram.inc), include files (mr30.inc and id.h), and system generation procedure description file (makefile) from the configuration file.

```
A> cfg30  -mv  lbp.cfg

MR30 system configurator V.3.30.01
Copyright 2003 RENESAS TECHNOLOGY CORPORATION
AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED.
MR30 version ==> V.3.30 Release 1

A>
```

Figure 4.4 Configurator Execution

4.2.4 System generation

Execute the make command [46] to generate the system.

```
A> nmake -f  makefile
as30 -F -Dtest=1 crt0mr.a30
nc30 -c task.c
ln30 @ln30.sub

A>
```

Figure 4.5 System Generation

4.2.5 Writing ROM

Using the lmc30 load module converter, convert the absolute module file into a ROM writable format and then write it into ROM. Or read the file into the debugger and debug it.

[46] It is possible for MR30 to use only "make" command compatible to UNIX standard. To use MS-DOS, use "make" command(for instance, "nmake" command attached to C-compiler make by Microsoft Corporation compatible to UNIX. For "make" command interchangeable to UNIX, refer to the release note. This paragraph describes an example for case when "nmake" command interchangeable to UNIX is executed.

Chapter 5 Detailed Applications

5.1 Program Coding Procedure in C Language

5.1.1 Task Description Procedure

1. **Describe the task as a function.**
   To register the task for the MR30, enter its function name in the configuration file. When, for instance, the function name "task()" is to be registered as the task ID number 3, proceed as follows.

```
task[3]{
        entry_address   = task();
        stack_size      = 100;
        priority        = 3;
};
```

2. **At the beginning of file, be sure to include "mr30.h" which is in system directory as well as "id.h" which is in the current directory. That is, be sure to enter the following two lines at the beginning of file.**

```
#include <mr30.h>
#include "id.h"
```

3. **No return value is provided for the task start function. Therefore, declare the task start function as a void function.**
4. **A function that is declared to be static cannot be registered as a task.**
5. **It isn't necessary to describe ext_tsk() at the exit of task start function.[47]If you exit the task from the subroutine in task start function, please describe ext_tsk() in the subroutine.**
6. **Don't describe extern declaration nor prototype declaration if system call is issued from your program.**
7. **It is also possible to describe the task startup function, using the infinite loop.**

```
#include <mr30.h>
#include "id.h"
void task(void)
{
        /* process */
}
```

Figure 5.1 Example Infinite Loop Task Described in C Language

[47] The task is ended by ext_tsk() automatically if #pramga TASK is declared in the MR30. Similarly, it is ended by ext_tsk when returned halfway of the function by return sentence.

```
#include <mr30.h>

#include "id.h"

void task(void)
{
        for(;;){
                /* process */

        }
}
```

Figure 5.2 Example Task Terminating with ext_tsk() Described in C Language

8. When designating a task, use a character string consisting of "ID_" and task function name.[48]

```
wup_tsk(ID_main);
```

9. When designating an eventflag, semaphore, mailbox, or memorypool, use a character string consisting of "ID_" and the name defined in the configuration file.

Suppose that the eventflag is defined as follows in the configuration file.

```
flag[1]{
        name    = abc;
};
```

To designate this eventflag, proceed as follows.

```
set_flg(ID_abc,&setptn);
```

10. When designating the cyclic handler or alarm handler, use a character string consisting of "ID_" and handler start function name. To designate the cyclic handler "cyc()," for instance, proceed as follows.

```
act_cyc(ID_cyc,TCY_ON);
```

11. When a task is reactivated by the sta_tsk() system call after it has been terminated by the ter_tsk() system call, the task itself starts from its initial state.[49] However, the external variable and static variable are not automatically initialized when the task is started. The external and static variables are initialized only by the startup program (crt0mr.a30), which actuates before MR30 startup.

12. The task executed when the MR30 system starts up is setup.

13. The variable storage classification is described below.

The MR30 treats the C language variables as indicated in Table 5.1.

[48] The configurator generates the "id.h" file which converts the task ID number to the associated character string for task designation. That is, "id.h" is used to make the #define declaration for converting the character string consisting of "ID_" and task start function name to the task ID number.

[49] Started beginning with the task start function at the initial priority level and with the wake-up count cleared.

Table 5.1 C Language Variable Treatment

Variable storage class	Treatment
Global Variable	Variable shared by all tasks
Non-function static variable	Variable shared by the tasks in the same file
Auto Variable Register Variable Static variable in function	Variable for specific task

5.1.2 Writing OS-dependent Interrupt Handler

When describing the OS-dependent interrupt handler in C language, observe the following precautions.

1. **Describe the OS-dependent interrupt handler as a function [50]**
2. **Be sure to use the void type to declare the interrupt handler start function return value and argument.**
3. **At the beginning of file, be sure to include "mr30.h" which is in the system directory as well as "id.h" which is in the current directory.**
4. **Do not use the ret_int system call in the interrupt handler.[51]**
5. **Don't describe extern declaration nor prototype declaration if system call is issued from your program.**
6. **The static declared functions can not be registered as an interrupt handler.**

```
#include <mr30.h>
#include "id.h"
void inthand(void)
{
        /* process */
        iwup_tsk(ID_main);
}
```

Figure 5.3 Example of OS-dependent Interrupt Handler

[50] A configuration file is used to define the relationship between handlers and functions.
[51] When an OS-dependent interrupt handler is declared with #pragma INTHANDLER ,code for the ret_int system call is automatically generated.

5.1.3 Writing OS-independent Interrupt Handler

When describing the OS-independent interrupt handler in C language, observe the following precautions.

1. **Be sure to declare the return value and argument of the interrupt handler start function as a void type.**
2. **No system call can be issued from an OS-independent interrupt handler.**
   NOTE: If this restriction is not observed, the software may malfunction.
3. **A function that is declared to be static cannot be registered as an interrupt handler.**
4. **If you want multiple interrupts to be enabled in an OS-independent interrupt handler, always make sure that the OS-independent interrupt handler is assigned a priority level higher than other OS-dependent interrupt handlers.[52]**

```
#include <mr30.h>

#include "id.h"

void inthand(void)
{
        /* process */
}
```

Figure 5.4 Example of OS-independent Interrupt Handler

[52] If you want the OS-independent interrupt handler to be assigned a priority level lower than OS-dependent interrupt handlers, change the description of the OS-independent interrupt handler to that of the OS-dependent interrupt handler.

5.1.4 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in C language, observe the following precautions.

1. **Describe the cyclic or alarm handler as a function.[53]**
2. **Be sure to declare the return value and argument of the interrupt handler start function as a void type.**
3. **At the beginning of file, be sure to include "mr30.h" which is in the system directory as well as "id.h" which is in the current directory.**
4. **The static declared functions cannot be registered as a cyclic handler or alarm handler.**
5. **Don't describe extern declaration nor prototype declaration if system call is issued from your program.**
6. **The cyclic handler and alarm handler are invoked by a subroutine call from a system clock interrupt handler.**

```
#include <mr30.h>

#include "id.h"

void cychand(void)
{
        /*process */
}
```

Figure 5.5 Example Cyclic Handler Written in C Language

[53] The handler-to-function name correlation is determined by the configuration file.

5.2 Program Coding Procedure in Assembly Language

This section describes how to write an application using the assembly language.

5.2.1 Writing Task

This section describes how to write an application using the assembly language.

1. **Be sure to include "mr30.inc" at the beginning of file.**
2. **For the symbol indicating the task start address, make the external declaration.[54]**
3. **Be sure that an infinite loop is formed for the task or the task is terminated by the ext_tsk system call.**

```
                .INCLUDE mr30.inc ----- (1)
                .GLB    task    ----- (2)

        task:
                        ; process
                jmp   task      ----- (3)
```

Figure 5.6 Example Infinite Loop Task Described in Assembly Language

```
                .INCLUDE mr30.inc
                .GLB    task

        task:
                        ; process
                ext_tsk
```

Figure 5.7 Example Task Terminating with ext_tsk Described in Assembly Language

4. **The initial register values at task startup are 0(zero) except the PC, SB, R0 and FLG registers.**
5. **When specifying a task, use a character string that consists of the task's start symbol name plus "ID_" as you specify it.[55]**

```
wup_tsk  #ID_task
```

6. **When specifying an eventflag, semaphore, or mailbox, use a character string that consists of the name defined in the configuration file plus "ID_" as you specify it.**

   For example, assume that the semaphore is defined in the configuration file as follows:

```
semaphore[1]{
        name            = abc;
};
```

   To specify this semaphore, write your specification as follows:

```
sig_sem  #ID_abc
```

7. **When specifying a cyclic handler or alarm handler, use a character string that con-**

[54] Use the .GLB pseudo-directive

[55] The configurator generates an instruction necessary to convert the task's ID number into a character string to specify the task in the file "mr30.inc".That is to say, the EQU declaration necessary to convert the character string consisting of the task's start symbol name plus "ID_" into that task's ID number is make in "mr30.inc".

sists of the handler's start symbol name plus "ID_" as you specify it.

For example, if you want to specify a cyclic handler "cyc," write your specification as follows:

```
act_cyc  #ID_cyc,#TCY_ON
```

8. Set a task that is activated at MR30 system startup in the configuration file [56]

[56] The relationship between task ID numbers and tasks(program) is defined in the configuration file.

5.2.2 Writing OS-dependent Interrupt Handler

When describing the OS-dependent interrupt handler in assembly language, observe the following precautions

1. **At the beginning of file, be sure to include "mr30.inc" which is in the system directory.**
2. **For the symbol indicating the interrupt handler start address, make the external declaration(Global declaration).[57]**
3. **Make sure that the registers used in a handler are saved at the entry and are restored after use.**
4. **Return to the task by ret_int system call.**

```
        .INCLUDE mr30.inc               ------(1)
        .GLB    inth                    ------(2)

inth:
        ;  Registers used are saved to a stack   ------(3)
        iwup_tsk  #ID_task1
                :
                process
                :

        ;  Registers used are restored  ------(3)

        ret_int                         ------(4)
```

Figure 5.8 Example of OS-depend interrupt handler

[57] Use the .GLB peudo-directive.

5.2.3 Writing OS-independent Interrupt Handler

1. **For the symbol indicating the interrupt handler start address, make the external declaration (public declaration).**
2. **Make sure that the registers used in a handler are saved at the entry and are restored after use.**
3. **Be sure to end the handler by REIT instruction.**
4. **No system calls can be issued from an OS-independent interrupt handler.**
   NOTE: If this restriction is not observed, the software may malfunction.
5. **If you want multiple interrupts to be enabled in an OS-independent interrupt handler, always make sure that the OS-independent interrupt handler is assigned a priority level higher than other OS-dependent interrupt handlers.[58]**

```
                .GLB    inthand                 ----- (1)

        inthand:
                ; Registers used are saved to a stack    ----- (2)
                ; interrupt process
                ; Registers used are restored   ----- (2)
                REIT                            ----- (3)
```

Figure 5.9 Example of OS-independent Interrupt Handler of Specific Level

[58] If you want the OS-independent interrupt handler to be assigned a priority level lower than OS-dependent interrupt handlers, change the description of the OS-independent interrupt handler to that of the OS-dependent interrupt handler.

5.2.4 Writing Cyclic Handler/Alarm Handler

When describing the cyclic or alarm handler in Assembly Language, observe the following precautions.

1. **At the beginning of file, be sure to include "mr30.inc" which is in the system directory.**
2. **For the symbol indicating the handler start address, make the external declaration.[59]**
3. **Always use the RTS instruction (subroutine return instruction) to return from cyclic handlers and alarm handlers.**

   For examples:

```
.INCLUDE        mr30.inc        ----- (1)
.GLB            cychand         ----- (2)

cychand:
                :
        ; handler process
                :

        rts                     ----- (3)
```

Figure 5.10 Example Handler Written in Assembly Language

[59] Use the .GLB pseudo-directive.

5.3 The Use of INT Instruction

MR30 has INT instruction interrupt numbers reserved for issuing system calls as listed in Table 5.2. For this reason, when using software interrupts in a user application, do not use interrupt numbers 63 through 48 and be sure to use some other numbers.

Table 5.2 Interrupt Number Assignment

Interrupt No.	System calls Used
32	System calls that can be issued from only tasks
33	System calls that can be issued from only task-independent sections. System calls that can be issued from both tasks and task-independent section.
34	ret_int system call
35	dis_dsp system call
36	loc_cpu system call
37	ext_tsk system call
38	System calls that can be issued from only tasks
39	System calls that can be issued from only task-independent sections. System calls that can be issued from both tasks and task-independent section.
40	extension system call
41 ~ 47	Reserved for future extension

5.4 The Use of registers of bank

The registers of bank is 0, when a task starts on MR30.

MR30 does not change the registers of bank in processing kernel.

You must pay attention to the followings.

- Don’t change the regisers of bank in processing a task.
- If an interrupt handler with regisers of bank 1 have multiple interrupts of an interrupt handler with regisers of bank 1 , the program can not execute normally.

5.5 Regarding Interrupts

5.5.1 Types of Interrupt Handlers

MR30's interrupt handlers consist of OS-dependent and OS-independent interrupt handlers.

The following shows the definition of each type of interrupt handler.

- OS-dependent interrupt handler
  The OS-dependent interrupt handler is defined as one that satisfies one of the following two conditions:
  - ♦ Interrupt handlers issuing a system call
  - ♦ Interrupt handlers including multiple interrupt handlers issuing a system call

  The OS-dependent interrupt handler's IPL value must be below the OS interrupt disable level (system.IPL) (IPL = 0 to system.IPL)[60]

- OS-independent interrupt handler
  The OS-independent interrupt handler is defined as one that satisfies both of the following two conditions:
  - ♦ Interrupt handlers not issuing a system call
  - ♦ Interrupt handlers that do not have multiple interrupts of interrupt handlers issuing a system call (system clock interrupt handler)

  The OS-independent interrupt handler's IPL value must be between (system.IPL + 1) to 7. Namely, the OS-independent interrupt handler's IPL value cannot be set below the OS-independent interrupt disable level.

Figure 5.11 shows the relationship between the OS-independent and OS-dependent interrupt handlers where the OS interrupt disable level is set to 3.

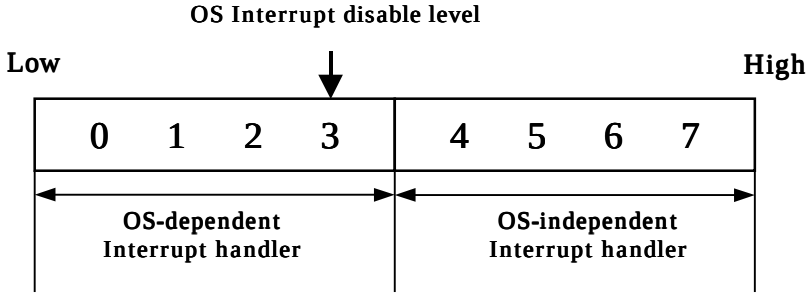


Figure 5.11 Interrupt handler IPLs

5.5.2 The Use of Non-maskable Interrupt

An NMI interrupt and Watchdog Timer interrupt have to use be a task-independent interrupt handller. If they are a task-dependent interrupt handler, the program will not work normally.

[60] system.IPL is set by the configuration file.

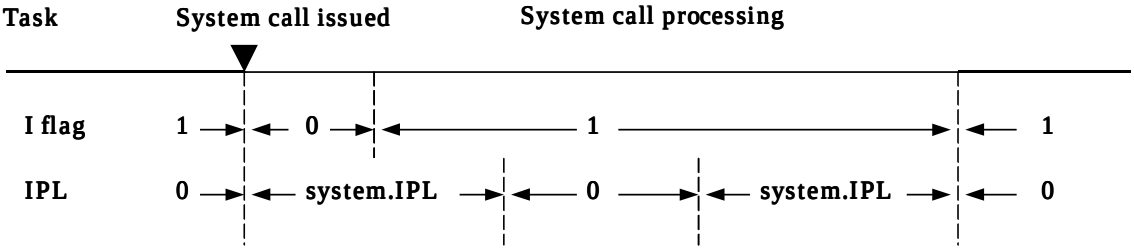
5.5.3 Controlling Interrupts

Interrupt enable/disable control in a system call is accomplished by IPL manipulation. The IPL value in a system call is set to the OS interrupt disable level (system.IPL) in order to disable interrupts for the OS-dependent interrupt handler. In sections where all interrupts can be enabled, it is returned to the initial IPL value when the system call was invoked.

Figure 5.12 shows the interrupt enable flag and IPL status in a system call.

- For system calls that can be issued from only task

When the I flag before issuing a system call is 1.



When the I flag before issuing a system call is 0.

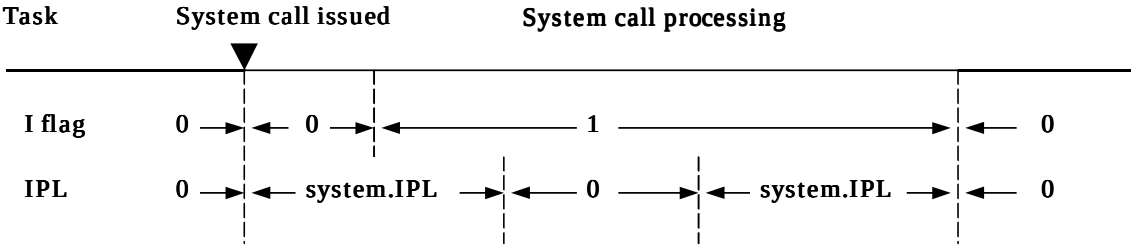


Figure 5.12 Interrupt control in a System Call that can be Issued from only a Task

- For system calls that can be issued from only task-independent section or from both task-independent section and task

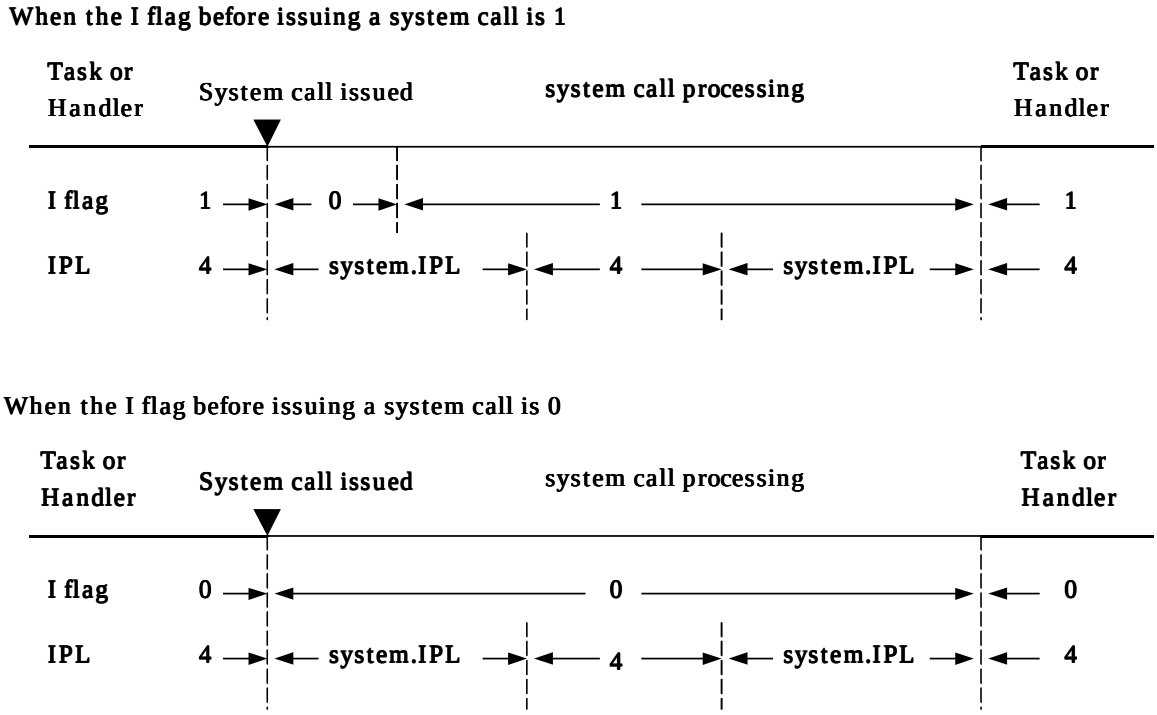


Figure 5.13 Interrupt control in a System Call that can be Issued from a Task-independent

As shown in Figure 5.12 and Figure 5.13, the interrupt enable flag and IPL change in a system call. For this reason, if you want to disable interrupts in a user application, Renesas does not recommend using the method for manipulating the interrupt disable flag and IPL to disable the interrupts.

The following two methods for interrupt control are recommended:

1. **Modify the interrupt control register (SFR) for the interrupt you want to be disabled.**
2. **Use system calls loc_cpu and unl_cpu.**
   The interrupts that can be controlled by the loc_cpu system call are only the OS-dependent interrupt. Use method 1 to control the OS-independent interrupts.

5.6 Regarding Delay Dispatching

MR30 has four system calls related to delay dispatching.

- dis_dsp
- ena_dsp
- loc_cpu
- unl_cpu

The following describes task handling when dispatch is temporarily delayed by using these system calls.

1. When the execution task in delay dispatching is preempted

While dispatch is disabled, even under conditions where the task under execution should be preempted, no time is dispatched to new tasks that are in an executable state. Dispatching to the tasks to be executed is delayed until the dispatch disabled state is cleared. When dispatch is being delayed.

- Task under execution is in a RUN state and is linked to the ready queue
- Task to be executed after the dispatch disabled state is cleared is in a READY state and is linked to the highest priority ready queue (among the queued tasks).

2. isus_tsk,irsm_tsk during dispatch delay

In cases when isus_tsk is issued from an interrupt handler that has been invoked in a dispatch disabled state to the task under execution (a task to which dis_dsp was issued) to place it in a SUSPEND state. During delay dispatching.

- The task under execution is handled inside the OS as having had its delay dispatching cleared. For this reason, in isus_tsk that has been issued to the task under execution, the task is removed from the ready queue and placed in a SUSPEND state. Error code E_OK is returned. Then, when irsm_tsk is issued to the task under execution, the task is linked to the ready queue and error code E_OK is returned. However, tasks are not switched over until delay dispatching is cleared.
- The task to be executed after disabled dispatching is re-enabled is linked to the ready queue.

3. rot_rdq, irot_rdq during dispatch delay

When rot_rdq (TPRI_RUN = 0) is issued during dispatch delay, the ready queue of the own task's priority is rotated. Also, when irot_rdq (TPRI_RUN = 0) is issued, the ready queue of the executed task's priority is rotated. In this case, the task under execution may not always be linked to the ready queue. (Such as when isus_tsk is issued to the executed task during dispatch delay.)

4. Precautions

- No system call (e.g., slp_tsk, wai_sem) can be issued that may place the own task in a wait state while in a state where dispatch is disabled by dis_dsp or loc_cpu.
- ena_dsp and dis_dsp cannot be issued while in a state where interrupts and dispatch are disabled by loc_cpu.
- Disabled dispatch is re-enabled by issuing ena_dsp once after issuing dis_dsp several times.
  The above status transition can be summarized in Table 5.3 below.

Table 5.3 Interrupt and_ Dispatch Status Transition by dis_dsp and loc_cpu

Status No.	Contents of Statusdis		dis_dsp is executed	ena_dsp is executed	loc_cpu is executed	unl_cpu is executed
	Interrupt	Dispatch				
1	Enabled	Enabled	→ 2	→ 1	→ 3	→ 1
2	Enabled	Disabled	→ 2	→ 1	→ 3	→ 1
3	Disabled	Disabled	×	×	→ 3	→ 1

5.7 Regarding Initially Activated Task

MR30 allows you to specify a task that starts from a READY state at system startup. This specification is made by setting the configuration file.

Refer to page 105 for details on how to set.

5.8 Modifying MR30 Startup Program

MR30 comes with two types of startup programs as described below.

- start.a30
  This startup program is used when you created a program using the assembly language.

- crt0mr.a30
  This startup program is used when you created a program using the C language.

  This program is derived from "start.a30" by adding an initialization routine in C language.

The startup programs perform the following:

- Initialize the processor after a reset.
- Initialize C language variables (crt0mr.a30 only).
- Set the system timer.
- Initialize MR30's data area.

Copy these startup programs from the directory indicated by environment variable "LIB30" to the current directory.

If necessary, correct or add the sections below:

- Setting processor mode register
  Set a processor mode matched to your system to the processor mode register. (102th line in crt0mr.a30)

- Adding user-required initialization program
  When there is an initialization program that is required for your application, add it to the 190th line in the C language startup program (crt0mr.a30).

  Comment out the 192th – 192th line in the C language startup program (crt0mr.a30) if no standard I/O function is used.

5.8.1 C Language Startup Program (crt0mr.a30)

Figure 5.14 shows the C language startup program(crt0mr.a30).

```
 1 ; ***************************************************************
 2 ;
 3 ;      MR30 start up program for C language
 4 ;      COPYRIGHT(C) 2003 RENESAS TECHNOLOGY CORPORATION
 5 ;      AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 6 ;
 7 ; ***************************************************************
 8 ; $Id: crt0mr.a30,v 1.44 2003/08/22 13:00:34 muraki Exp $
 9
10       .list   OFF
11       .include       c_sec.inc
12       .include       mr30.inc
13       .include       sys_rom.inc
14       .include       sys_ram.inc
15       .list   ON
16
17 ;------------------------------------------------------------------------
18 ; SBDATA area definition
19 ;------------------------------------------------------------------------
20       .glb    __SB__
21       .SB     __SB__
22
23 ;========================================================================
24 ; Initialize Macro declaration
25 ;------------------------------------------------------------------------
26 N_BZERO .macro  TOP_,SECT_
27       mov.b   #00H, R0L
28       mov.w   #(TOP_ & 0FFFFH), A1
29       mov.w   #sizeof SECT_, R3
30       sstr.b
31       .endm
32
33 N_BCOPY .macro  FROM_,TO_,SECT_
34       mov.w   #(FROM_ & 0FFFFH),A0
35       mov.b   #(FROM_>>16),R1H
36       mov.w   #TO_,A1
37       mov.w   #sizeof SECT_, R3
38       smovf.b
39       .endm
40
41 BZERO   .macro  TOP_,SECT_
42       push.w  #sizeof SECT_ >> 16
43       push.w  #sizeof SECT_ & 0ffffh
44       pusha   TOP_>>16
45       pusha   TOP_ & 0ffffh
46
47       .glb    _bzero
48       jsr.a   _bzero
49       .endm
50 ;
51
52 BCOPY   .macro  FROM_,TO_,SECT_
53       push.w  #sizeof SECT_ >> 16
54       push.w  #sizeof SECT_ & 0ffffh
55       pusha   TO_>>16
56       pusha   TO_ & 0ffffh
57       pusha   FROM_>>16
58       pusha   FROM_ & 0ffffh
59
60       .glb    _bcopy
61       jsr.a   _bcopy
62       .endm
63
64 ;========================================================================
65 ; Interrupt section start
66 ;------------------------------------------------------------------------
```

```
 67       .glb    __SYS_INITIAL
 68       .section       MR_KERNEL,CODE,ALIGN
 69 __SYS_INITIAL:
 70 ;---------------------------------------------------------------------
 71 ; after reset,this program will start
 72 ;---------------------------------------------------------------------
 73       ldc     #(__Sys_Sp&0FFFFH),ISP  ; set initial ISP
 74
 75       mov.b   #2H,0AH
 76       mov.b   #00,PMOD              ; Set Processor Mode Regsiter
 77       mov.b   #0H,0AH
 78       ldc     #00H,FLG
 79       ldc     #(__Sys_Sp&0FFFFH),fb
 80       ldc     #__SB__,sb
 81
 82 ; +-----------------------------------------------------+
 83 ; |    MR RAM DATA 0(zero) clear             |
 84 ; +-----------------------------------------------------+
 85       N_BZERO MR_RAM_top,MR_RAM
 86
 87 ; +-----------------------------------------------------+
 88 ; |    ISSUE SYSTEM CALL DATA INITIALIZE             |
 89 ; +-----------------------------------------------------+
 90 .if    __MR_NODBG == 1
 91 .else
 92       mov.b   #0,__DBG_MODE
 93 .endif
 94
 95 ;=====================================================================
 96 ; NEAR area initialize.
 97 ;---------------------------------------------------------------------
 98 ; bss zero clear
 99 ;---------------------------------------------------------------------
100       N_BZERO bss_SE_top,bss_SE
101       N_BZERO bss_SO_top,bss_SO
102
103       N_BZERO bss_NE_top,bss_NE
104       N_BZERO bss_NO_top,bss_NO
105
106 ;---------------------------------------------------------------------
107 ; initialize data section
108 ;---------------------------------------------------------------------
109       N_BCOPY data_SEI_top,data_SE_top,data_SE
110       N_BCOPY data_SOI_top,data_SO_top,data_SO
111       N_BCOPY data_NEI_top,data_NE_top,data_NE
112       N_BCOPY data_NOI_top,data_NO_top,data_NO
113
114 ;=====================================================================
115 ; FAR area initialize.
116 ;---------------------------------------------------------------------
117 ; bss zero clear
118 ;---------------------------------------------------------------------
119       BZERO   bss_FE_top,bss_FE
120       BZERO   bss_FO_top,bss_FO
121
122 ;---------------------------------------------------------------------
123 ; Copy edata_E(O) section from edata_EI(OI) section
124 ;---------------------------------------------------------------------
125       BCOPY   data_FEI_top,data_FE_top,data_FE
126       BCOPY   data_FOI_top,data_FO_top,data_FO
127
128       ldc     #(__Sys_Sp&0FFFFH),     sp
129       ldc     #(__Sys_Sp&0FFFFH),     fb
130
131 ;=====================================================================
132 ; Initialize standard I/O
133 ;---------------------------------------------------------------------
134 ;       .glb    _init
135 ;       jsr.a   _init
136
137 ;---------------------------------------------------------------------
138 ; Set System IPL
139 ; and
```

```
140 ; Set Interrupt Vector
141 ;---------------------------------------------------------------------
142       mov.b   #0,R0L
143       mov.b   #__SYS_IPL,R0H
144       ldc     R0,FLG                ; set system IPL
145       ldc     #((__INT_VECTOR>>16)&0FFFFH),INTBH
146       ldc     #(__INT_VECTOR&0FFFFH),INTBL
147
148 .IF USE_TIMER
149 ; +-----------------------------------------------------+
150 ; |    System timer interrupt setting                   |
151 ; +-----------------------------------------------------+
152       mov.b   #stmr_mod_val,stmr_mod_reg     ;set timer mode
153 ;     mov.b   #1H,0AH
154 ;     bset    6,07H
155       mov.b   #stmr_int_IPL,stmr_int_reg     ;set timer IPL
156 ;     bclr    6,07H
157 ;     mov.b   #0,0AH
158       mov.w   #stmr_cnt,stmr_ctr_reg         ;set interval count
159       or.b    #stmr_bit+1,stmr_start         ;system timer start
160 .ENDIF
161
162 ; +-----------------------------------------------------+
163 ; |    System timer initialize                        |
164 ; +-----------------------------------------------------+
165 .IF    USE_SYSTEM_TIME
166       MOV.W   #__D_Sys_TIME_L, __Sys_time+4
167       MOV.W   #__D_Sys_TIME_M, __Sys_time+2
168       MOV.W   #__D_Sys_TIME_H, __Sys_time
169 .ENDIF
170
171 ; +-----------------------------------------------------+
172 ; |    User Initial Routine ( if there are )          |
173 ; +-----------------------------------------------------+
174 ;
175
176
177 ;     jmp     __MR_INIT      ; for Separate ROM
178
179 ; +-----------------------------------------------------+
180 ; |    Initalization of System Data Area              |
181 ; +-----------------------------------------------------+
182 ;     .section      MR_KERNEL,CODE,ALIGN
183
184       .glb    __init_sys,__init_tsk,__END_INIT
185 __MR_INIT:
186       jsr.W   __init_sys
187       jsr.W   __init_tsk
188
189 .if    __MR_TIMEOUT
190       .glb    __init_tout
191       jsr.w   __init_tout
192 .endif
193
194 .if    __NUM_FLG
195       .glb    __init_flg
196       jsr.W   __init_flg
197 .endif
198
199 .if    __NUM_SEM
200       .glb    __init_sem
201       jsr.W   __init_sem
202 .endif
203
204 .if    __NUM_MBX
205       .glb    __init_mbx
206       jsr.W   __init_mbx
207 .endif
208
209 .IF    ALARM_HANDLER
210       .glb    __init_alh
211       jsr.W   __init_alh
212 .ENDIF
```

```
213
214 .IF    CYCLIC_HANDLER
215       .glb   __init_cyh
216       jsr.W  __init_cyh
217 .ENDIF
218
219 ; Fixed Memory Pool
220 .if    __NUM_MPL
221       .glb   __init_mpl
222       jsr.W  __init_mpl
223 .endif
224
225 ; Variable Memory Pool
226 .IF __MR_HEAPSIZE
227       .glb   __init_memblk,__init_vmpl
228
229       jsr.w  __init_vmpl
230       jsr.w  __init_memblk
231 .ENDIF
232
233 .if    __MR_NODBG == 1
234 .else
235       or.b   #80H,__DBG_MODE
236 .endif
237
238 __END_INIT:
239 ; +-------------------------------------------------------+
240 ; |    Start initial active task                    |
241 ; +-------------------------------------------------------+
242       mov.w  #1, A0
243 __start_task:
244       lde.b  __D_INIT_START-1[A0],A1
245       jeq    __start_end
246       mov.w  A0,R1               ;move counter to R1
247       mov.w  A1,A0               ;set task id
248       mov.w  #0,R2               ;set start code
249       mov.w  #TFN_ISTA_TSK,R0             ;set func code
250       .ASSERT 'ista_tsk' >> ..file@.mrc
251       int    #33
252       mov.w  R1,A0
253       inc.w  A0
254       jmp.B  __start_task
255 __start_end:
256       .glb   __rdyq_search
257       jmp.W  __rdyq_search
258
259 ; +-----------------------------------------+
260 ; |           Define Dummy                |
261 ; +-----------------------------------------+
262       .glb   __SYS_DMY_INH
263 __SYS_DMY_INH:
264       reit
265
266 ; +-----------------------------------------+
267 ; |           exit() function             |
268 ; +-----------------------------------------+
269       .glb   _exit,$exit
270 _exit:
271 $exit:
272       jmp    _exit
273
274 ; +-----------------------------------------+
275 ; | Syscall exit rouitne(trace error code)
276 ; +-----------------------------------------+
277       .glb   __sys_end
278 __sys_end:
279 .if    __MR_NODBG == 1
280 .else
281       .glb   __SYS_TRC
282       mov.w  R0,__SYS_TRC
283       mov.w  R1,__SYS_TRC
284       mov.w  R2,__SYS_TRC
285       mov.w  R3,__SYS_TRC
```

```
286       nop
287       nop
288 .endif
289       REIT
290
291 .if USE_TIMER
292 ; +-------------------------------------------+
293 ; |      System clock interrupt handler       |
294 ; +-------------------------------------------+
295       .SECTION      MR_KERNEL,CODE,ALIGN
296       .glb          __SYS_STMR_INH, __SYS_TIMEOUT
297       .glb          __DBG_MODE,__SYS_ISS
298 __SYS_STMR_INH:
299 ; process issue system call
300 .if    __MR_NODBG == 1
301 .else
302       tst.b   #1H,__DBG_MODE
303       jz     __proc_timer
304       pushm   R0,R1,R2,R3,A0
305       mov.w   __SYS_ISS,R0
306       mov.w   __SYS_ISS+2,R1
307       mov.w   __SYS_ISS+4,R2
308       mov.w   __SYS_ISS+6,R3
309       mov.w   __SYS_ISS+8,A0
310       cmp.w   #108,R0
311       jeq    __INT_33
312       cmp.w   #110,R0
313       jeq    __INT_33
314       cmp.w   #64,R0
315       jnc    __INT_33       ; if(R0 < 64) jmp __INT_33
316       cmp.w   #68,R0
317       jnc    __INT_33OR39    ; if((R0 >= 64)&&(R0 < 68)) jmp __INT_33OR39
318       cmp.w   #76,R0
319       jnc    __INT_33       ; if((R0 >= 68)&&(R0 < 76)) jmp __INT_33
320       jmp.b   __INT_39
321 __INT_33OR39:
322 .if    FAR_MSG_MODEL
323       int    #39
324 .else
325       int    #33
326 .endif
327       jmp.b   __END_ISS_SYS
328 __INT_39:
329       int    #39
330       jmp.b   __END_ISS_SYS
331 __INT_33:
332       int    #33
333 __END_ISS_SYS:
334       mov.w   R0,__SYS_ISS    ; error code
335       mov.w   R1,__SYS_ISS+2  ;
336       mov.w   R2,__SYS_ISS+4  ;
337       mov.w   R3,__SYS_ISS+6  ;
338       and.b   #0FEH,__DBG_MODE
339       popm    R0,R1,R2,R3,A0
340 .endif
341
342 __proc_timer:
343       pushm   R3,R0
344       stc    FLG,R0
345       mov.w   R0,__user_FLG         ;save user IPL
346       mov.b   #__SYS_IPL,R0H        ;change to system IPL
347       ldc    R0,FLG
348       fset    I
349
350       mov.w   __user_FLG,R3
351       and.w   #0ff00H,R3
352
353 ; System timer interrupt handler
354       _STMR_hdr
355       popm    R3,R0
356       ret_int
357 .endif
358
```

```
359         .end
```

Figure 5.14 C Language Startup Program (crt0mr.a30)

The following explains the content of the C language startup program (crt0mr.a30).

1. **Incorporate a section definition file [12 in Figure 5.14]**
2. **Incorporate an include file for MR30 [13 in Figure 5.14]**
3. **Incorporate a system ROM area definition file [14 in Figure 5.14]**
4. **Incorporate a system RAM area definition file [15 in Figure 5.14]**
5. **This is the initialization program __SYS_INITIAL that is activated immediately after a reset. [98 - 254 in Figure 5.14]**
   - Setting the System Stack pointer [99 in Figure 5.14]
   - Setting the processor mode register [101- 103 in Figure 5.14]
   - Setting the SB,FB register [104 - 108 in Figure 5.14]
   - Initial set the C language. [123 - 154 in Figure 5.14] When using no standard input/output functions, remove the lines 191 and 192 in Figure 5.14.
   - Setting OS interrupt disable level [163 - 165 in Figure 5.14]
   - Setting the address of interrupt vector table [166 in Figure 5.14]
   - Set MR30's system clock interrupt [171-176 in Figure 5.14]
   - Initial set MR30's system timer [181-185 in Figure 5.14]
6. **Initial set parameters inherent in the application [190 in Figure 5.14]**
7. **Initialize the RAM data used by MR30 [197-241 in Figure 5.14]**
8. **Activate the initial startup task. [251 in Figure 5.14]**
9. **This is a system clock interrupt handler [287-295 in Figure 5.14]**

5.9 Memory Allocation

This section describes how memory is allocated for the application program data.

Use the section file provided by MR30 to set memory allocation.

MR30 comes with the following two types of section files:

- asm_sec.inc
  This file is used when you developed your applications with the assembly language.
  Refer to page 90 for details about each section.

- c_sec.inc
  This file is used when you developed your applications with the C language.
  c_sec.inc is derived from "asm_sec.inc" by adding sections generated by C compiler NC30.
  Refer to page 90 for details about each section.

Modify the section allocation and start address settings in this file to suit your system.

The following shows how to modify the section file.

e.g.

```
If you want to change the program section start address from F0000H to F1000H
           .section        program
           .org    0F0000H ; Correct this address to F1000H

                   ↓

           .section        program

           .org    0F1000H ;
```

5.9.1 Section Allocation of start.a30

The section allocation of the sample startup program for the assembly language "start.a30" is defined in "asm_sec.inc".

Edit "asm_sec.inc" if section reallocation is required.

The following explains each section that is defined in the sample section definition file "asm_sec.inc".

- MR_RAM_DBG section
  This section is stored MR30's debug function RAM data.

  This section must be mapped in the Internal RAM area.

- MR_RAM section
  This section is where the RAM data, MR30's system management data, is stored that is referenced in absolute addressing.

  This section must be mapped between 0 and FFFFH(near area).

- stack section
  This section is provided for each task's user stack and system stack.

  This section must be mapped between 0 and FFFFH(near area).

- MR_HEAP section
  This section stores the variable-size memorypool.

- MR_KERNEL section
  This section is where the MR30 kernel program is stored.

- MR_CIF section
  This section stores the MR30 C language interface library.

- MR_ROM section
  This section stores data such as task start addresses that area referenced by the MR30 kernel.

- program section
  This section stores user programs.

  This section is not used by the MR30 kernel at all. Therefore, you can use this section as desired.

- INTERRUPT_VECTOR section

- FIX_INTERRUPT_VECTOR section
  This section stores interrupt vectors. The start address of this section varies with the type of M16C/60,30,20,10 series microcomputer used. The address in the sample startup program is provided for use by the M16C/60,30,20,10 series micro-computers. This address must be modified if you are using a microcomputer of some other group.

5.9.2 Section Allocation of crt0mr.a30

The section allocation of the sample startup program for the C language "crt0mr.a30" is defined in "c_sec.inc".

Edit "c_sec.inc" if section reallocation is required.

The sections defined in the sample section definition file "c_sec.inc" include the following sections that are defined in the section definition file "asm_sec.inc" of the sample startup program for the assembly language.

- data_SE section
- bss_SE section
- data_SO section
- bss_SO section
- data_NE section
- bss_NE section
- data_NO section
- bss_NO section
- rom_NE section
- rom_NO section
- data_FE section
- bss_FE section
- data_FO section
- bss_FO section
- rom_FE section
- rom_FO section
- data_SEI section
- data_SOI section
- data_NEI section
- data_NOI section
- data_FEI section
- data_FOI section

  These sections are those that are generated by NC30. These sections are not defined in the section file for the assembly language.

  Refer to the NC30 manual for details.

The diagram below shows the section allocation in the sample startup program. (See Figure 5.15)

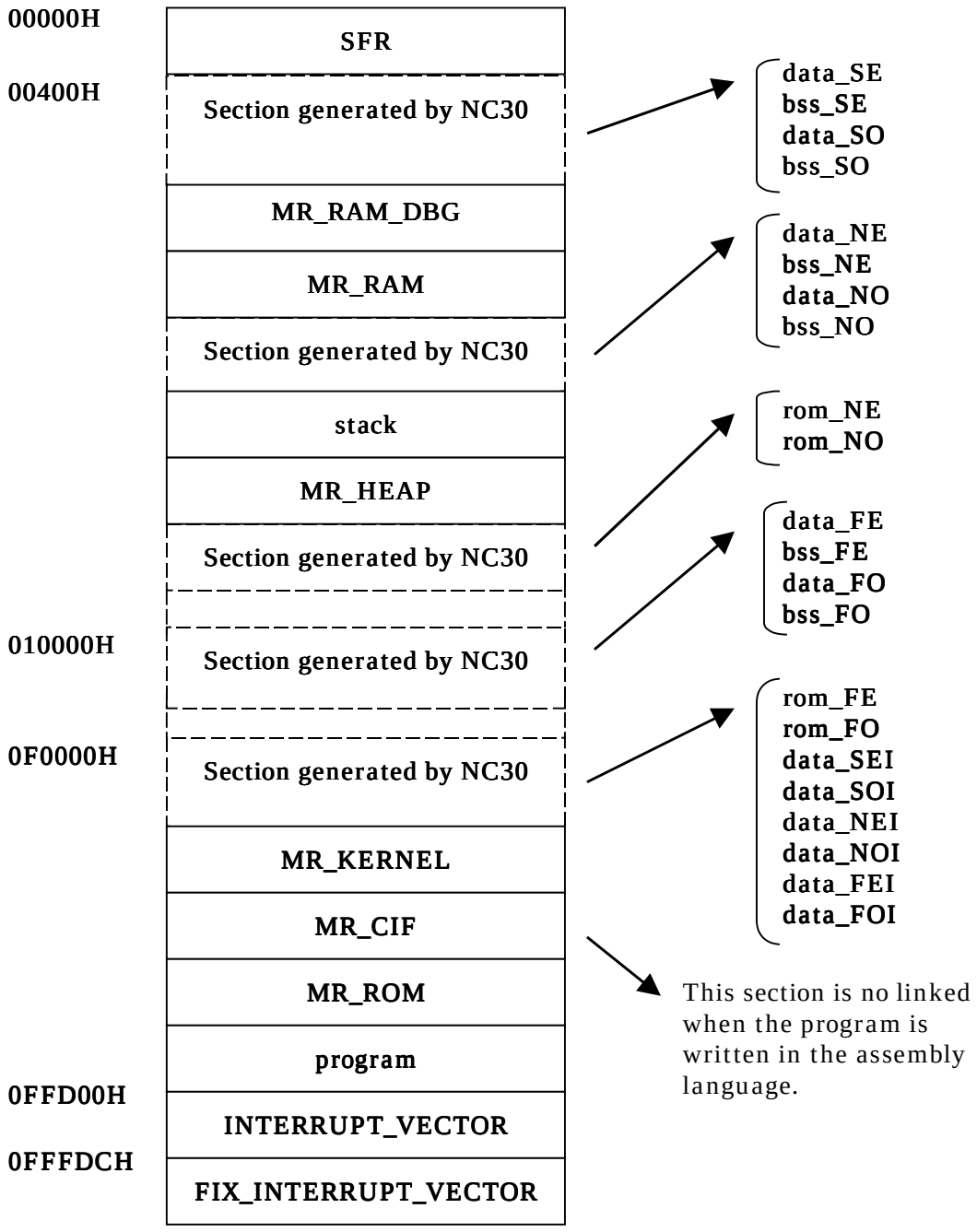


Figure 5.15 Selection Allocation in C Language Startup Program

5.10 Cautions for each microcontroler

5.10.1 To use the M16C/62 group MCUs

- To use the memory expansion function in memory space expansion mode 1 (1.2M available memory)

  Locate the MR30 kernel (MR_KERNEL section) between addresses 30000H and FFFFFH.

- To use the memory expansion function in memory space expansion mode 2 (4M available memory)

  Locate the MR30 kernel (MR_KERNEL section) between addresses 3C0000H and 3FFFFFH.

5.10.2 To use the M16C/6N group MCUs

Please append the following program to the point of the MR30's system timer setting in the startup program.(The setting point of MR30's system timer is lines 160 in crt0mr.a30 or lines 73 in start.a30. These startup files are in "MR30's install directory\LIB30" directory.)

If you select no division by changing the value of the peripheral function clock register, need not append the following program.

```
;+-------------------------------------------------------------+
;|     System timer interrupt setting                          |
;+-------------------------------------------------------------+
        mov.b  #stmr_mod_val,stmr_mod_reg     ; set timer mode
;       mov.b   #1H,0AH
;       bset    6,07H
        mov.b   #stmr_int_IPL,stmr_int_reg     ; set timer IPL
;       bclr    6,07H
;       mov.b   #0,0AH
        mov.w   #stmr_cnt_stmr_ctr_reg  ; set interval count

        mov.b   stmr_mod_reg,R0L               <---- append
        and.b   #0C0H,R0L                      <---- append
        jnz     __MR_SYSTIME_END               <---- append
        mov.w   #stmr_cnt/2,stmr_ctr_reg       <---- append
__MR_SYSTIME_END:                              <---- append

        or.b    #stmr_bit+1,stmr_start
```

Chapter 6 Using Configurator

6.1 Configuration File Creation Procedure

When applications program coding and startup program modification are completed, it is then necessary to register the applications program in the MR30 system.

This registration is accomplished by the configuration file.

6.1.1 Configuration File Data Entry Format

This chapter describes how the definition data are entered in the configuration file.

Comment Statement

A statement from '//' to the end of a line is assumed to be a comment and not operated on.

End of statement

Statements are terminated by ';'.

Numerical Value

Numerical values can be entered in the following format.

1. Hexadecimal Number

Add "0x" or "0X" to the beginning of a numerical value, or "h" or "H" to the end. If the value begins with an alphabetical letter between A and F with "h" or "H" attached to the end, be sure to add "0" to the beginning. Note that the system does not distinguish between the upper- and lower-case alphabetical characters (A-F) used as numerical values.[61]

2. Decimal Number

Use an integer only as in '23'. However, it must not begin with '0'.

3. Octal Numbers

Add '0' to the beginning of a numerical value of 'O' or 'o' to end.

4. Binary Numbers

Add 'B' or 'b' to the end of a numerical value. It must not begin with '0'.

Table 6.1 Numerical Value Entry Examples

Hexadecimal	0xf12 0Xf12 0a12h 0a12H 12h 12H
Decimal	32
Octal	017 17o 17O
Binary	101110b 101010B

[61] The system distinguishes between the upper- and lower-case letters except for the numbers A-F and a-f.

It is also possible to enter operators in numerical values. Table 6.2 lists the operators available.

Table 6.2 Operators

Operator	Priority	Direction of computation
()	High	From left to right
- (Unary_minus)		From right to left
* / %		From left to right
+ - (Binary_minus)	Low	From loft to right

Numerical value examples are presented below.

- 123
- 123 + 0x23
- (23/4 + 3) * 2
- 100B + 0aH

Symbol

The symbols are indicated by a character string that consists of numerals, upper- and lower-case alphabetical letters, _(underscore), and ?, and begins with a non-numeric character.

Example symbols are presented below.

- _TASK1
- IDLE3

Function Name

The function names are indicated by a character string that consists of numerals, upper and lower-case alphabetical letters,'$'(dollar) and '_'(underscore), begins with a non-numeric character, and ends with '()'.

The following shows an example of a function name written in the C language.

- main()
- func()

When written in the assembly language, the start label of a module is assumed to be a function name.

Frequency

The frequency is indicated by a character string that consist of numerals and . (period), and ends with MHz. The numerical values are significant up to six decimal places. Also note that the frequency can be entered using decimal numbers only.

Frequency entry examples are presented below.

- 16MHz
- 8.1234MHz

It is also well to remember that the frequency must not begin with . (period).

Time

The time is indicated by a character string that consists of numerals and . (period), and ends with ms. The time values are effective up to three decimal places when the character string is terminated with ms. Also note that the time can be entered using decimal numbers only.

- 10ms
- 10.5ms

It is also well to remember that the time must not begin with . (period).

The time of day

The time of day is expressed using 3-word (48-bit) data which consists of 1-word (16-bit) numbers joined with : (colon), as shown in the example below.

- 23 : 0x02 : 100B

If one or two high-order numbers of a total of three numbers are omitted, the omitted numbers are regarded as 0. For instance, 12 is equivalent to 0:0:12.

6.1.2 Configuration File Definition Items

The following definitions[62] are to be formulated in the configuration file

- System definition
- System clock definition
- Respective maximum number of items
- Task definition
- Eventflag definition
- Semaphore definition
- Mailbox definition
- Fixed-size Memorypool definition
- Variable-size Memorypool definition
- Cyclic handler definition
- Alaram handler definition
- Interrupt vector definition

[(System Definition Procedure)]

<< Format >>

```
// System Definition
system{
    stack_size      = System stack size ;
    priority        = Maximum value of priority ;
    message_size    = Message size;
    system_IPL      = OS interrupt disable level;
    timeout = Timeout function ;
    task_pause      = Task Pause ;
};
```

<< Content >>

1. **System stack size**

   [(Definition format)] Numeric value

   [(Definition range)] 1 or more

   Define the total stack size used in system call and interrupt processing.

[62] All items except task definition can omitted. If omitted, definitions in the default configuration file are referenced.

2. Maximum value of priority (value of lowest priority)

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum value of priority used in MR30's application programs. This must be the value of the highest priority used.

3. Message Size

[(Definition format)] Numeric value

[(Definition range)] 16 or 32

Specify the message size of mailbox. Specify 16 for 16-bit message data, or 32 for 32- bit message data. Omitting this assumes 16.

4. OS interrupt disable level

[(Definition format)] Numeric value

[(Definition range)] 0 ~ 7

Set the IPL value in system calls, that is, the OS interrupt disable level.[63]

5. Timeout function

[(Definition format)] Symbol

[(Definition range)] YES or NO

Specify YES when using or NO when not using tslp_tsk, twai_flg, twai_sem and trcv_msg.

6. Task Pause

[(Definition format)] Symbol

[(Definition range)] YES or NO

Specify YES when usig or NO when not using the Task Pause function of PD30’s OS Debug Function.

[(System Clock Definition Procedure)]

<< Format >>

```
// System Clock Definition
clock{
     mpu_clock  = MPU clock ;
     timer      = Timers used for system clock ;
     IPL        = System clock interrupt priority level ;
     unit_time  = Unit time of system clock;
     initial_time = Initial value of system time ;
};
```

[63] If you define 0 here, no system clock interrupt and OS-dependent interrupt handlers can be used at all.

<< Content >>

1. MPU clock

[(Definition format)] Frequency(in MHz)

[(Definition range)] None

Define the MPU operating clock frequency of the M16C in MHz.

2. Timers used for system clock

[(Definition format)] Symbol

[(Definition range)]
- 16C/60 Series
  A0 to A4, B0 to B5, OTHER, NOTIMER
- 16C/30 Series
  A0 to A3 B1 to B2, OTHER, NOTIMER
- 16C/20 Series
  A0 to A7 B0 to B5, X0 to X2, OTHER, NOTIMER
- 16C/10 Series
  OTHER, NOTIMER

Define the hardware timers used for the system clock.

The configurator don't check the timer setting for each series.

For M16C/10 Series, you set OTHER and describe the timer setting in the startup file.

If you do not use a system clock, define "NOTIMER."

3. System clock interrupt priority level

[(Definition format)] Numeric value

[(Definition range)] 1 ~ (OS interrupt disable level in system definition)

Define the priority level of the system clock timer interrupt. The value set here must be smaller than the OS interrupt disable level.

Interrupts whose priority levels are below the interrupt level defined here are not accepted during system clock interrupt handler processing.

4. Unit time of system clock

[(Definition format)] Time(in ms)

[(Definition range)] $\frac{1}{\text{MPU clock}(mpu\_clock)} \sim \frac{32 \times 65535}{\text{MPU clock}(mpu\_clock)}$

Define the unit time of the system clock (system clock interrupt generation intervals) in ms.

The minimum value of this period can be calculated using the equation. However, no value that is less than 0.001 ms is allowed to set even if the calculation gives the minimum value less than 0.001 ms.

Therefore, if you set the value less than 0.001 ms in the configuration file, the configurator will return such an error message as shown below.

[Example of Error Messages]

```
---------------------------------------------------------------------
cfgXX Error : illegal clock.unit_time --> <0> near line YY (smp.cfg)
---------------------------------------------------------------------
```

When setting the system clock's pulse period in the configuration file, make sure that this period of time is greater than the processing time of the system clock interrupt handler operating in OS. Note that the value of the processing time varies with the type of MCU and the operating condition.

For details of calculating the processing time of the system clock interrupt handler, see the reference manual.

5. Initial value of system time

[(Definition format)] Time of day

[(Definition range)] 0 : 0 : 0 ~ 0x7FFF : 0xFFFF : 0xFFFF

Define the initial value of the system time. If you do not use the functions based on system time (e.g., set_tim, get_tim, alarm handler), there is no need to set this item. If this item is not defined, system clock interrupt handler processing is optimized automatically. Note, however, that if a default value is defined in the default configuration file, said processing is not optimized.

[(Definition respective maximum numbers of items)]
This definition is to be given only in forming the separate ROMs.[64]

Here, define respective maximum numbers of items to be used in two or more applications.

<< Format >>

```
// Max Definition
maxdefine{
    max_task = the maximum number of tasks defined ;
    max_flag = the maximum number of eventflags defined ;
    max_mbx  = the maximum number of mailboxes defined ;
    max_sem  = the maximum number of semaphores defined ;
    max_mpl  = the maximum number of fixed-size
                 memorypools defined ;
    max_cyh  = the maximum number of cyclic handlers
                 defined ;
    max_alh  = the maximum number of alarm handlers
                 defined ;
};
```

<< Contents >>

1. The maximum number of tasks defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of tasks defined.

[64] For details of forming the into separate ROMs, see page 143.

2. The maximum number of eventflags defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of eventflags defined.

3. The maximum number of mailboxes defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of mailboxes defined.

4. The maximum number of semaphores defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of semaphores defined.

5. The maximum number of fixed-size memorypools defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of fixed-size memorypools defined.

6. The maximum number of cyclic activation handlers defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

The maximum number of cyclic handler defined

7. The maximum number of alarm handler defined

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 255

Define the maximum number of alarm handlers defined.

[(Task definition)]

<< Format >>

```
 // Tasks Definition
task[ ID No. ]{
    entry_address   = Start task of address ;
    stack_size              = User stack size of task ;
    priority                = Initial priority of task ;
    context         = Registers used ;
    initial_start   = Initial startup status ;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each task ID number.

1. **Start address of task**

   [(Definition format)] Symbol or function name

   [(Definition range)] None

   Define the entry address of a task. When written in the C language, add () at the end or _at the beginning of the function name you have defined.

   The function name defined here causes the following declaration statement to be output in the id.h file:

   ```
   #pragma TASK Function Name
   ```

2. **User stack size of task**

   [(Definition format)] Numeric value

   [(Definition range)] 6 or more

   Define the user stack size for each task. The user stack means a stack area used by each individual task. MR30 requires that a user stack area be allocated for each task, which amount to at least 6 bytes.

3. **Initial priority of task**

   [(Definition format)] Numeric value

   [(Definition range)] 1 to (maximum value of priority in system definition)

   Define the priority of a task at startup time.

   As for MR30's priority, the lower the value, the higher the priority.

4. Regisers Used

[(Definition format)] Symbol[,Symbol,....]

[(Definition range)] Selected from R0,R1,R2,R3,A0,A1,SB,FB

Define the registers used in a task. MR30 handles the register defined here as a context. Specify the R1 register because task startup code is set in it when the task starts.

However, the registers used can only be selected when the task is written in the assembly language. Select all registers when the task is written in the C language. When selecting a register here, be sure to select all registers that store system call parameters used in each task.

MR30 kernel does not change the registers of bank.

If this definition is omitted, it is assumed that all registers are selected.

5. Initial startup status

[(Definition format)] Symbol

[(Definition range)] ON or OFF

If you specify ON, the task is placed in a READY state when the system initially starts up.

The start code of initial start task is 0.

[(Eventflag definition)]
This definition is necessary to use Eventflag function.

<< Format >>

```
// Eventflag Definition
flag[ ID No. ]{
   name            = Name ;
};
           :
           :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each eventflag ID number.

1. Name

[(Definition format)] Symbol

[(Definition range)] None

Define the name with which an eventflag is specified in a program.

[(Semaphore definition)]
This definition is necessary to use Semaphore function.

<< Format >>

```
// Semaphore Definition
semaphore[ ID No. ]{
    name                    = Name;
    initial_count   = Initial value of semaphore
                              counter;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each semaphore ID number.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a semaphore is specified in a program.

2. **Initial value of semaphore counter**

   [(Definition format)] Numeric value

   [(Definition range)] 0 ~ 32767

   Define the initial value of the semaphore counter.

[(Mailbox definition)]
This definition is necessary to use Mailbox function.

<< Format >>

```
// Mailbox Definition
mailbox[ ID No. ]{
    name            = Name;
    buffer_size     = Maximum number of mailbox messages;
};
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the name with which a mailbox is specified in a program.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a mailbox is specified in a program.

2. **The maximum number of messages**

   [(Definition format)] Numeric Value

   [(Definition range)] 0 ~ 16383

   Define the maximum number of messages that can be stored in a mailbox. An error is returned if an attempt is made to store messages exceeding this limit.

[(Fixed-size memorypool definition)]
This definition is necessary to use Fixed-size memorypool function.

<< Format >>

```
// Fixed Memorypool Definition
memorypool[ ID No. ]{
    name           = Name ;
    section = Section Name ;
    num_block      = Number of blocks for Memorypool ;
    siz_block      = Block size of Memorypool ;
};
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each memorypool ID number.

1. **Name**

   [(Definition format)] Symbol

   [(Definition range)] None

   Define the name with which a memorypool is specified in a program.

2. Section name

[(Definition format)] Symbol

[(Definition range)] None

Define the section name allocated memorypool. Be sure to allocate this section in your section file(asm_sec.inc or c_sec.inc).

If you don't define this section name in your file(c_sec.inc or asm_sec.inc), allocate this section in MR_RAM section.

3. Number of block

[(Definition format)] Numeric value

[(Definition range)] 1~16

Define all Number of block for memorypool.

4. Size

[(Definition format)] Numeric value

[(Definition range)] 1~ 65535

Define the size of one memorypool block. When this definition is formulated, the RAM capacity of the memorypool is set to (number of blocks) x (size).

[(Variable-size memorypool definition)]
This definition is necessary to use Variable-size memorypool function.

<< Format >>

```
// Variable-Size Memorypool Definition
variable_memorypool[ ID No. ]{
   max_memsize     = The maximum memory block size to be allocated;
   heap_size       = Memorypool size ;
};
```

Assign 1 to the ID number.

The memorypool is allocated in MR_HEAP section.

<< Content >>

1. The maximum memory block size to be allocated

[(Definition format)] Numeric value

[(Definition range)] 1 ~ 65520

Specify, within an application program, the maximum memory block size to be allocated.

2. Memorypool size

[(Definition format)] Numeric value

[(Definition range)] 16 ~ 524288

Specify a memorypool size.

Round off a block size you specify to the optimal block size among the four block sizes, and acquires memory having the rounded-off size from the memorypool.

The following equations define the block sizes:

a = (((max_memsize+(X-1))/ (X × 8))+1) × 8
b = a × 2
c = a × 4
d = a × 8

max_memsize: the value specified in the configuration file
X: data size for block control (8 byte per a block control)

Variable-size memorypool function needs 8 byte RAM area per a block control. Memorypool size needs a size more than a, b, c or d that can be stored max_memsize + 8.

[(Cyclic handler definition)]
This definition is necessary to use Cyclic handler function.

<< Format >>

```
// Cyclic Handlar Definition
 cyclic_hand[ ID No. ]{
    interval_counter        = Intervals ;
    mode                    = Mode ;
    entry_address   = Start address ;
 };
            :
            :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each cyclic handler ID number.

1. Intervals

[(Definition format)] Numeric value

[(Definition range)] 1 to 32767

Define the intervals at which time the cyclic handler is activated periodically. The intervals here must be defined in the same unit of time as the system clock's unit time that is defined in system clock definition item. If the system clock's unit time is 10 ms and you want the cyclic handler to be activated at 10-second intervals, for example, the intervals here must be set to 1000.

2. Mode

[(Definition format)] Symbol

[(Definition range)] TCY_ON or TCY_OFF

Define the initial mode of the cyclic handler. One of the following two modes can be defined here:

- TCY_OFF
  In this mode, the cyclic handler is activated by a act_cyc system call.
- TCY_ON
  In this mode, the cyclic handler is activated simultaneously when the system starts up.

3. Start Address

[(Definition format)] Symbol or Function Name

[(Definition range)] None

Define the start address of the cyclic handler.

The function name defined here causes the following declaration statement to be output in the id.h file:

```
#pragma CYCHANDLER function name
```

[(Alarm handler definition)]
This definition is necessary to use Alarm handler function.

<< Format >>

```
// Alarm Handlar Definition
alarm_hand[ ID No. ]{
   time                    = Startup time;
   entry_address   = Start address;
};
          :
          :
```

The ID number must be in the range of 1 to 255. The ID number can be omitted.

If omitted, numbers are automatically assigned sequentially beginning with the smallest.

<< Content >>

Define the following for each alarm handler ID number.

1. **Startup time**

   [(Definition format)] Time of day

   [(Definition range)] 0 : 0 : 0 ~ 0x7FFF : 0xFFFF : 0xFFFF

   Define the startup time of the alarm handler.

2. **Start address**

   [(Definition format)] Symbol or Function Name

   [(Definition range)] None

   Define the start address of the alarm handler. The function name defined here causes the following declaration statement to be output in the id.h file.

```
#pragma ALMHANDLER function name
```

[(Interrupt vector definition)]
This definition is necessary to use Interrupt function.

<< Format >>

```
// Interrupt Vector Definition
interrupt_vector[ Vector No. ]{
    os_int                = OS-dependent interrupt handler;
    entry_address   = Start address;
};
            :
            :
```

The vector number can be written in the range of 0 to 63 and 247 to 255. However, whether or not the defined vector number is valid depends on the microcomputer used

The relationship between interrupt causes and interrupt vector numbers for the M16C/80 series is shown in Table 6.3.

Configurator can't create an Initialize rutine (interrupt control register, interrupt causes etc.) for this defined interrupt. You nead to create that.

[Note]

Registers of bank 1 can not be specified in the configuration file. Insert declaration "#pragma INTERRUPT/B" after the "id.h" include command in the C language source file.

Example: #include <mr30.h>
#include "id.h"
#pragma INTERRUPT/B OS-independent interrupt handler function name

Registers of bank 1 in the OS-dependent interrupt handler can not be described in C language. You can describe in assembly language only. Describe the interrupt handler entrance and exit as follows:

(Make sure you clear B flag before issuing the ret_int system call.)

Example: interrupt:
fset B
:
fclr B
ret_int

MR30 kernel does not change the registers of bank.

NMI and Watch dog timer Interrupt can not be OS-independ interrupt handler.

<< Content >>

3. OS-dependent interrupt handler

[(Definition format)] Symbol

[(Definition range)] YES or NO

Define whether or not the handler is an OS-dependent interrupt handler.

If it is an OS-dependent interrupt handler, define YES; if it is an OS-independent interrupt handler, define NO.

If you define YES, the following declaration statement is output in the id.h file:

```
#pragma INTHANDLER fuction name
```

Or if you define NO, the following declaration statement is output in the id.h file:

```
#pragma INTERRUPT function name
```

4. Start address

[(Definition format)] Symbol or function name

[(Definition range)] None

Define the entry address of the interrupt handler. When written in the C language, add () at the end or at the beginning of the function name you have defined.

Table 6.3 Fixed-Interrupt Causes and Vector Numbers

	Interrupt vector number	Section Name
Undefined instruction	247	FIX_INTERRUPT_VECTOR
Over flow	248	FIX_INTERRUPT_VECTOR
BRK instruction	249	FIX_INTERRUPT_VECTOR
Address match	250	FIX_INTERRUPT_VECTOR
Single Step	251	FIX_INTERRUPT_VECTOR
Watch dog timer	252	FIX_INTERRUPT_VECTOR
DBC	253	FIX_INTERRUPT_VECTOR
NMI	254	FIX_INTERRUPT_VECTOR
Reset	255	FIX_INTERRUPT_VECTOR

6.1.3 Configuration File Example

The following is the configuration file example.

```
360 //*****************************************************************
361 //
362 //    Copyright 2003 RENESAS TECHNOLOGY CORPORATION
363 //    AND RENESAS SOLUTIONS CORPORATION
364 //
365 //    MR30 System Configuration File.
366 //
367 //*****************************************************************
368 // System Definition
369 system{
370             stack_size              = 0x20;
371             priority                = 3;
372             message_size            = 32;
373             system_IPL              = 6;
374             timeout                 = NO;
375 };
376 //System Clock Definition
377 clock{
378             mpu_clock               = 10MHz;
379             timer                   = A0;
380             IPL                     = 5;
381             unit_time               = 0.5ms;         // ms
382             initial_time            = 1:0x10:0xffff;
383 };
384 //Task Definition
385 task[1]{
386             entry_address           = _task1;
387             stack_size              = 0x20;
388             priority                = 1;
389             context                 = R0,R1,R2,A0;
390             initial_start           = ON;
391 };
392 task[2]{
393             entry_address           = _task2;
394             stack_size              = 512;
395             priority                = 2;
396             context                 = R0,R1,R2,A0;
397             initial_start           = OFF;
398 };
399 task[3]{
400             entry_address           = _task3;
401             stack_size              = 512;
402             priority                = 3;
403             context                 = R0,R1,R3,A0;
404             initial_start           = OFF;
405 };
406 //
407 flag[1]{
408             name            = flg1;
409 };
410 //
411 semaphore[1]{
412             name            = sem1;
413             initial_count   = 1;
414 };
415 //
416 mailbox[1]{
417             name            = mbx1;
418             buffer_size     = 3;
419 };
420 //
421 memorypool[1]{
422             name            = mpl1;
423             section         = FIX_MEM;
424             num_block       = 5;
425             siz_block       = 100;
```

```
426 };
427 //
428 variable_memorypool[1]{
429             max_memsize     = 400;
430             heap_size       = 1600;
431 };
432 //
433 cyclic_hand[1]{
434             interval_counter= 0xff;
435             mode            = TCY_OFF;
436             entry_address   = _cyh1;
437 };
438 //
439 alarm_hand[1]{
440             time            = 1:0xff:0xffff;
441             entry_address   = _alh1;
442 };
443 interrupt_vector[6]{
444             os_int          = YES;
445             entry_address   = _intr;
446     };
```

6.2 Configurator Execution Procedures

6.2.1 Configurator Overview

The configurator is a tool that converts the contents defined in the configuration file into the assembly language include file, etc.Figure 6.1 outlines the operation of the configurator.

1. Executing the configurator requires the following input files:

- Configuration file (XXXX.cfg)
  This file contains description of the system's initial setup items. It is created in the current directory.

- Default configuration file (default.cfg)
  This file contains default values that are referenced when settings in the configuration file are omitted. This file is placed in the directory indicated by environment variable "LIB30" or the current directory. If this file exists in both directories, the file in the current directory is prioritized over the other.

- makefile template files [65] (makefile.ews, makefile.dos, makefile, Makefile)
  This file is used as a template file when generating makefile.[66] (Refer to Section 6.2.4)

- mr30.inc template file(mr30.inc)
  This file serves as the template file of include file "mr30.inc". It resides in the directory indicated by environment variable "LIB30."

- MR30 version file (version)
  This file contains description of MR30's version. It resides in the directory indicated by environment variable "LIB30." The configurator reads in this file and outputs MR30's version information to the startup message.

2. When the configurator is executed, the files listed below are output.

Do not define user data in the files output by the configurator. Starting up the configurator after entering data definitions may result in the user defined data being lost.

- System data definition file (sys_rom.inc)
  This file contains definition of system settings.

- Include file (mr30.inc)
  This is an include file for the assembly language.

- System generation procedure description file(makefile)
  This file is used to generate the system automatically.

[65] The template file used for the EWS version is makefile.ews, and that for the DOS version is makefile.dos.
[66] This makefile is a system generation procedure description file that can be processed by UNIX standard make commands or those conforming to UNIX standards.

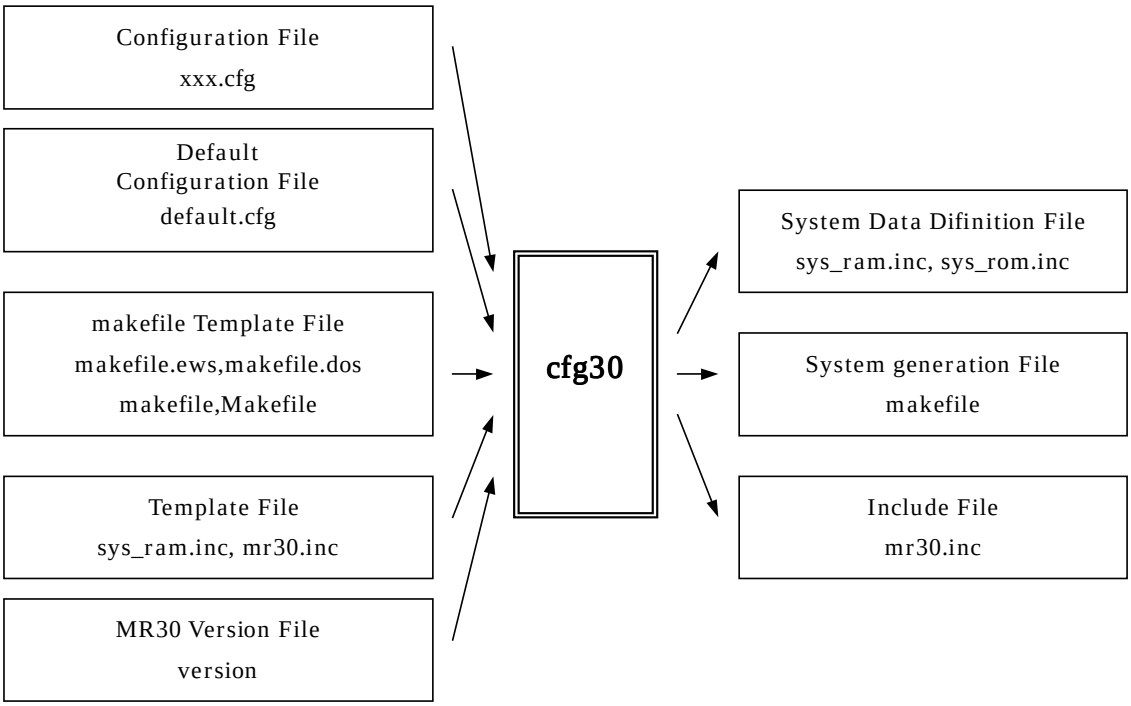


Figure 6.1 The operation of the Configurator

6.2.2 Setting Configurator Environment

Before executing the configurator, check to see if the environment variable "LIB30" is set correctly.

The configurator cannot be executed normally unless the following files are present in the directory indicated by the environment variable "LIB30":

- Default configuration file (default.cfg)
  This file can be copied to the current directory for use. In this case, the file in the current directory is given priority.

- System RAM area definition database file (sys_ram.inc)
- mr30.inc template file (mr30.inc)
- Section definition file(c_sec.inc or asm_sec.inc)
- Startup file(crt0mr.a30 or start.a30)
- makefile template file(makefile.ews or makefile.dos)
- MR30 version file(version)

6.2.3 Configurator Start Procedure

Start the configurator as indicated below.

```
A> cfg30  [-vmV]  Configuration file name
```

Normally, use the extension .cfg for the configuration file name.

Command Options

-v Option

Displays the command option descriptions and detailed information on the version.

-V Option

Displays the information on the files generated by the command.

-m Option

Creates the UNIX standard or UNIX-compatible system generation procedure description file (makefile). If this option is not selected, makefile creation does not occur.[67]

If the startup file (crt0mr.a30 or start.a30) and the section definition file are not in the current directory, the configurator copys them to the current directory form the directory indicated by the environment variable “LIB30”.

[67] UNIX standard "makefile" and one conforming to UNIX standards have a function to delete the work file by a "clean" target. Namely,if you want to delete the object file generated by the make command,for example,enter the following:
> make clean

6.2.4 makefile generate Function

The configurator follows the procedure below to generate makefile.

1. Examine the source file's dependency relationship.

Assuming that the files bearing extensions .c and .a30 in the current directory respectively to be the C language and the assembly language files, the configurator examines the dependency relationship of the files to be included by those.

Consequently, observe the following precautions when creating a source file:

- The source file must be placed in the current directory.
- Use the extension '.c' for the C language source file and '.a30' for the assembly language source file.

2. Write the file dependency relationship to makefile

Using "makefile" or "Makefile" in the current directory or "makefile.ews" or "makefile.dos" in the directory indicated by the environment variable "LIB30" as a template file, the configurator creates "makefile" in the current directory.

6.2.5 Precautions on Executing Configurator

The following lists the precautions to be observed when executing the configurator:

- If you have re-run the configurator, always be sure to execute make clean or delete all object files (extension .r30) and execute the make command. In this case, an error may occur during linking.
- Do not modify the strartup program name and the section definition file name. Otherwise, an error may be encountered when executing the configurator.
- The configurator cfg30 can only generate UNIX standard makefile or one conforming to UNIX standards. Namely, it does not generate MS-DOS standard makefile.

6.2.6 Configurator Error Indications and Remedies

If any of the following messages is displayed, the configurator is not normally functioning. Therefore, correct the configuration file as appropriate and the execute the configurator again.

Error messages

cfg30 Error : syntax error near line xxx (xxxx.cfg)
There is an syntax error in the configuration file.

cfg30 Error : not enough memory
Memory is insufficient.

cfg30 Error : illegal option --> <x>
The configurator's command option is erroneous.

cfg30 Error : illegal argument --> <xx>
The configurator's startup format is erroneous.

cfg30 Error : can't write open <XXXX>
The XXXX file cannot be created. Check the directory attribute and the remaining disk capacity available.

cfg30 Error : can't open <XXXX>
The XXXX file cannot be accessed. Check the attributes of the XXXX file and whether it actually exists.

cfg30 Error : can't open version file
The MR30 version file "version" cannnot be found in the directory indicated by the environment variable "LIB30".

cfg30 Error : can't open default configuration file
The default configuration file cannnot be accessed. "default.cfg" is needed in the current directory or directory "LIB30" specifying.

cfg30 Error : can't open configuration file <xxxx.cfg>
The configuration file cannot be accessed. Check that the file name has been properly designated.

cfg30 Error : illegal XXXX --> <xx> near line xxx (xxxx.cfg)
The value or ID number in definition item XXXX is incorrect. Check the valid range of definition.

cfg30 Error : Unknown XXXX --> <xx> near line xx (xxxx.cfg)
The symbol definition in definition item XXXX is incorrect. Check the valid range of definition.

cfg30 Error : too big XXXX's ID number --> <xx> (xxxx.cfg)
A value is set to the ID number in XXXX definition that exceeds the total number of objects defined.The ID number must be smaller than the total number of objects.

cfg30 Error : too big task[x]'s priority --> <xx> near line xxx (xxxx.cfg)
The initial priority in task definition of ID number x exceeds the priority in system definition.

cfg30 Error : too big IPL --> <xx> near line xxx (xxxx.cfg)
The system clock interrupt priority level for system clock definition item exceeds the value of IPL within system call of system definition item.

cfg30 Error : system timer's vector <x>conflict near line xxx
A different vector is defined for the system clock timer interrupt vector. Confirm the vector No.x for interrupt vector definition.

cfg30 Error : XXXX is not defined (xxxx.cfg)
"XXXX" item must be set in your configuration file.

cfg30 Error : system's default is not defined
These items must be set int the default configuration file.

cfg30 Error : double definition <XXXX> near line xxx (xxx.cfg)
XXXX is already defined. Check and delete the extra definition.

cfg30 Error : double definition XXXX[x] near line xxx (default.cfg)
cfg30 Error : double definition XXXX[x] near line xxx (xxxx.cfg)
The ID number in item XXXX is already registered. Modify the ID number or delete the extra definition.

cfg30 Error : you must define XXXX near line xxx (xxxx.cfg)
XXXX cannot be ommited.

cfg30 Error : you must define SYMBOL near line xxx (xxxx.cfg)
This symbol cannnot be omitted.

cfg30 Error : start-up-file (XXXX) not found
The start-up-file XXXX cannot be found in the current directory. The startup file "start.a30" or "crt0mr.a30" is required in the current directory.

cfg30 Error : bad start-up-file(XXXX)
There is unnecessary start-up-file in the current directory.

cfg30 Error : no source file
No source file is found in the current directory.

cfg30 Error : zero divide error near line xxx (xxxx.cfg)
A zero divide operation occured in some arithmetic expression.

cfg30 Error : task[X].stack_size must set XX or more near line xxx (xxxx.cfg)
You must set more than XX bytes.in task[x].stack_size.

cfg30 Error : “R0” must exist in task[x].context near line xxx (xxxx.cfg)
You must select R0 regiseter in task[x].context.

cfg30 Error : can’t define address match interrupt definition for Task Pause Function near line xxx (xxxx.cfg)

Another interrupt is defined in interrupt vector definition needed by Task Pause Function.

cfg30 Error : Set system timer [system.timeout = YES] near line xxx (xxxx.cfg)

Set clock.timer symbol except “NOTIMER”.

Warning messages

The following message are a warning. A warning can be ignored providing that its content is understood.

cfg30 Warning : system is not defined (xxxx.cfg)

cfg30 Warning : system.XXXX is not defined (xxxx.cfg)
System definition or system definition item XXXX is omitted in the configuration file.

cfg30 Warning : system.message_size is not defined (xxxx.cfg)
The message size definition is omitted in the system definition. Please specify message size (16 or 32) of the Mailbox function.

cfg30 Warning : task[x].XXXX is not defined near line xxx (xxxx.cfg)
The task definition item XXXX in ID number is omitted.

cfg30 Warning : Already definition XXXX near line xxx (xxxx.cfg)
XXXX has already been defined.The defined content is ignored, check to delete the extra definition.

cfg30 Warning : interrupt_vector[x]'s default is not defined (default.cfg)
The interrupt vector definition of vector number x in the default configuration file is missing.

cfg30 Warning : interrupt_vector[x]'s default is not defined near line xxx (xxxx.cfg)
The interrupt vector of vector number x in the configuration file is not defined in the default configuration file.

cfg30 Warning : Initial Start Task not defined
The task of task ID number 1 was defined as the initial startup task because no initial startup task is defined in the configuration file.

cfg30 Warning : system.stack_size is an uneven number near line xxx
cfg30 Warning : task[x].stack_size is an uneven number near line xxx
Please set even size in system.stack_size or task[x].stack_size.

Other messages

The following message are a warning message that is output only when generating makefile.The configurator skips the sections that have caused such a warning as it generates makefile.

cfg30 Error : xxxx (line xxx): include format error.
The file read format is incorrect. Rewrite it to the correct format.

cfg30 Warning : xxxx (line xxx): can't find <XXXX>

cfg30 Warning : xxxx (line xxx): can't find "XXXX"
The include file XXXX cannot be found. Check the file name and whether the file actually exists.

cfg30 Warning : over character number of including path-name

The path-name of include file is longer than 255 characters.

6.3 Editing makefile

Here you edit makefile the configurator generated, and set compilation options, libraries, and so on. The procedure for setting them is given below.

1. **NC30 command options**

   You define command options of the C compiler in "CFLAGS". Be sure to define the "-c" option.

2. **AS30 command options**

   You define command options of the assembler in "ASFLAGS".

3. **LN30 command options**

   You define command options of the linker in "LDFLAGS". There are no particular options you need to specify.

4. **Specifying libraries**

   You define libraries in "LIBS".

   The configurator picks up necessary libraries from the configuration file and from the current directory, and defines them in 'LIBS". Either add or delete libraries when necessary.

If you create the own makefile for MR30 system, be sure to describe the following 4 items in the makefile.

file.

5. **MR30 Library Specifications**

   The MR30 library varies according to the message size of the mailbox function. When using the 32-bit message size, you must specify libraries mr30lm.lib and c30mrlm.lib. When using the 16-bit message size, libraries mr30.lib and c30mr.lib must be specified.

6. **Compile Option Specifications**

   You must pay close attention to the specified compile options when compiling a file using a system call related to the mailbox functions. When using 32-bit message size, specify compile option "-Dfar_msg=1". This option does not need to be specified when using the 16-bit message size.

7. **Assemble Option Specifications**

   Make sure to specify assemble option "-F" when assembling the source file, described in the assemble language, which issues the system call.

8. **Process Before Linking**

   Before executing a link, make sure to execute the following two processes, in the order as are listed.

   1. mkmrtbl

   2. as30 mrtable.a30

   MR30 comes equipped with the mkmrtbl utility. Execute it in the directory where Configurator (cfg30) executes. If that is not the same directory where the system call file (XXX.mrc) and the r30 file are output by C Compiler or Assembler, you need to specify the directory at parameters of mkmrtbl as following. .

   Ex) mkmrtbl outputdir

Chapter 7 Application Creation Guide

7.1 Processing Procedures for System Calls from Handlers

When a system call is issued from a handler, task switching does not occur unlike in the case of a system call from a task. However, task switching occurs when a return from a handler [68] is made.

The processing procedures for system calls from handlers are roughly classified into the following three types.

1. **A system call from a handler that caused an interrupt during task execution**
2. **A system call from a handler that caused an interrupt during system call processing**
3. **A system call from a handler that caused an interrupt (multiplex interrupt) during handler execution**

[68] The system call can't be issued from OS-independent handler. Therefore, The handler described here does not include the OS-independent handler.

7.1.1 System Calls from a Handler That Caused an Interrupt during Task Execution

Scheduling (task switching) is initiated by the ret_int system call[69](See Figure 7.1).

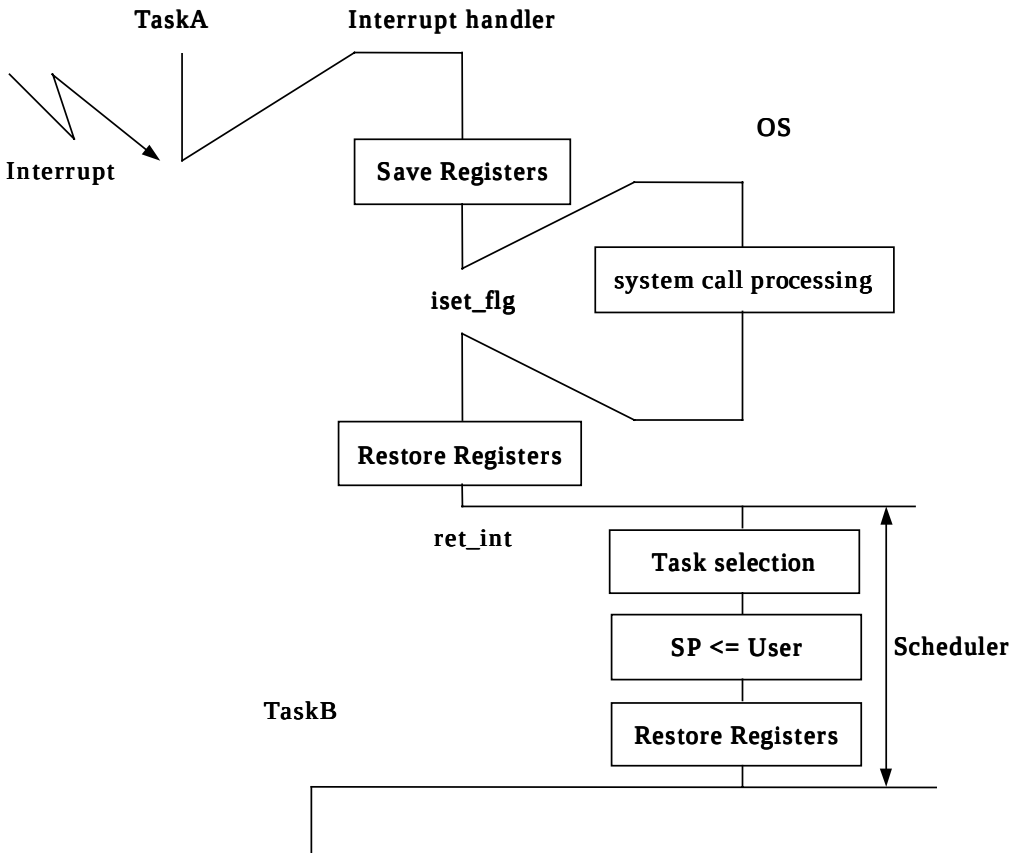


Figure 7.1 Processing Procedure for a System Call a Handler that caused an interrupt during Task Execution

[69] The ret_int system call is issued automatically when OS-dependent handler is written in C language (when #pragma INTHANDLER specified)

7.1.2 System Calls from a Handler That Caused an Interrupt during System Call Processing

Scheduling (task switching) is initiated after the system returns to the interrupted system call processing (See Figure 7.2).

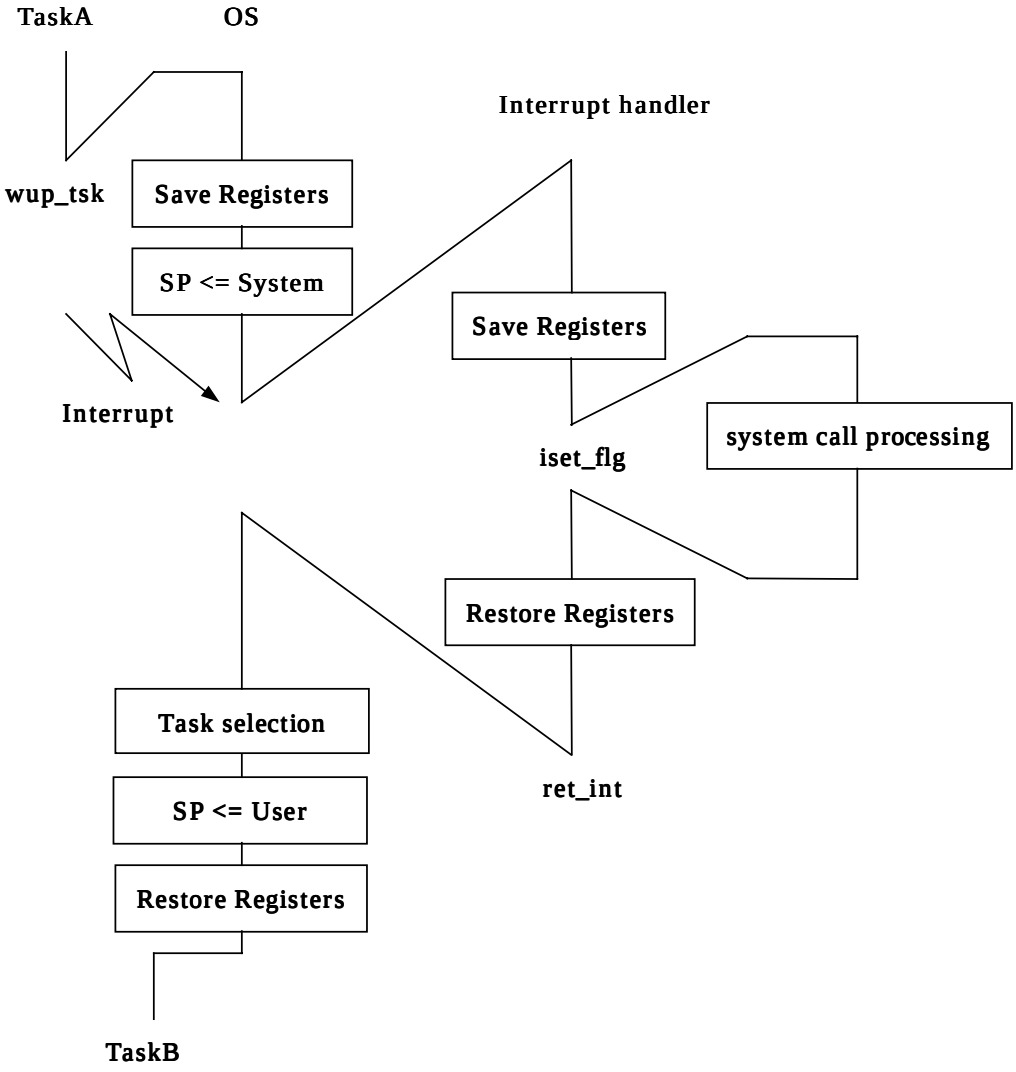


Figure 7.2 Processing Procedure for a System Call from a Handler that caused an interrupt during System Call Processing

7.1.3 System Calls from a Handler That Caused an Interrupt during Handler Execution

Let us think of a situation in which an interrupt occurs during handler execution (this handler is hereinafter referred to as handler A for explanation purposes). When task switching is called for as a handler (hereinafter referred to as handler B) that caused an interrupt during handler A execution issued a system call, task switching does not take place during the execution of the system call (ret_int system call) returned from handler B, but is effected by the ret_int system call from handler A (See Figure 7.3).

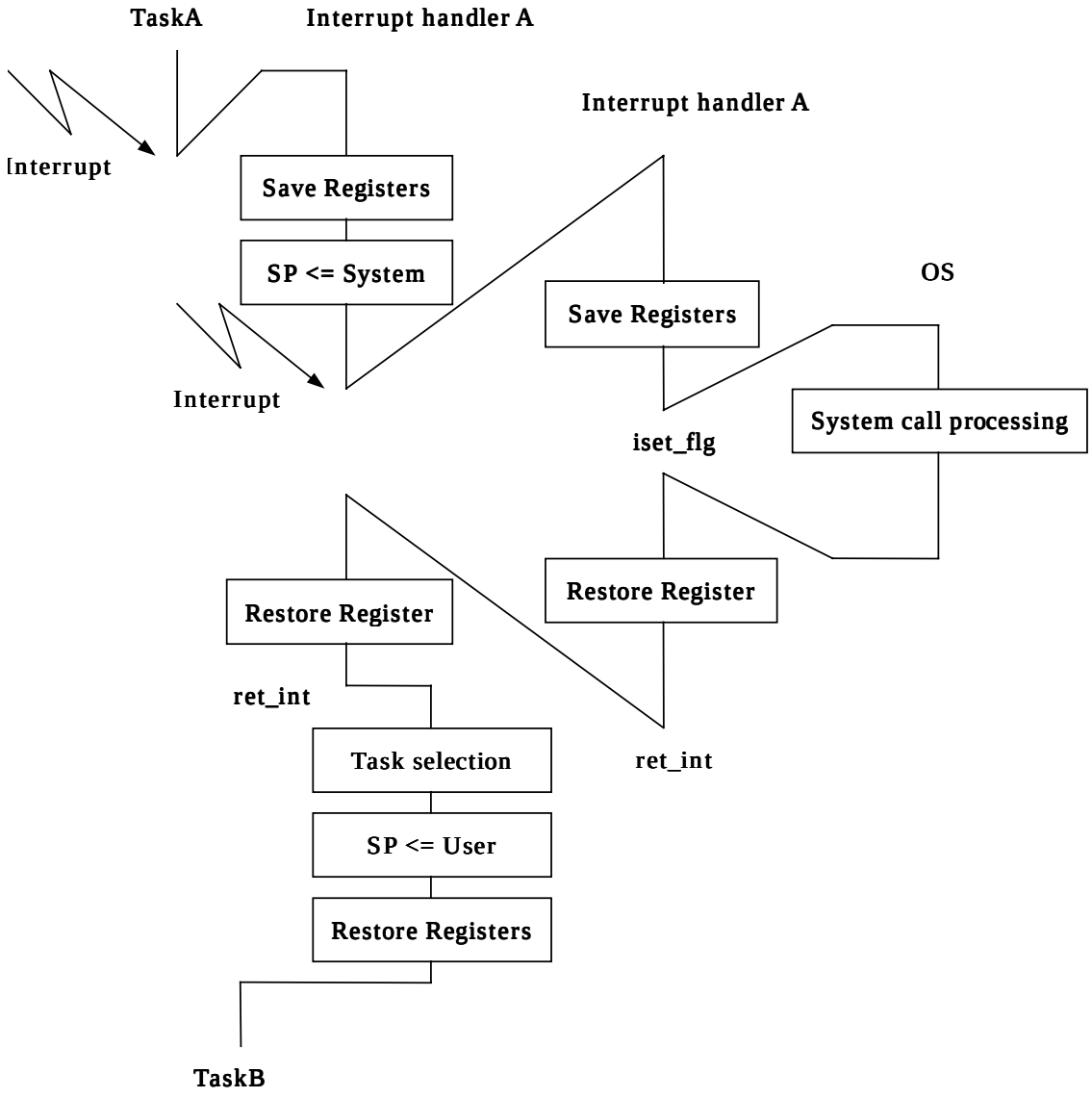


Figure 7.3 Processing Procedure for a system call from a Multiplex interrupt Handler

7.2 Calculating the Amount of RAM Used by the System

The RAM used by the MR30 kernel to manage tasks, etc. is placed in the MR_RAM section.

The RAM capacity used by MR30 in the MR_RAM section can be found by calculation according to Table 7.1 However, this does not include the stacks used by the system and tasks.

Refer to the reference manual for details on how to calculate the stack size.

Table 7.1 MR_RAM Method for Caluculating Size of MR_RAM Section

Area Name	Numbers of Bytes
System work area	4 + number of priority levels
System clock management area	6
Task management area	11 × number of tasks (Without Timeout)
	15 × number of tasks (With Timeout)
Timer queue management area	6
Cyclic handler management area	3 × number of cyclic handlers
Alarm handler management area	1
Eventflag management area	4 × number of Eventflag + 1 + (number of Eventflag -1)/8
Semaphore management area	3 × number of semaphore
Fixed-size memorypool management area	2 × number of Fixed-size memorypool
Variable-size memorypool management area	44
Mailbox management area	7 × number of mailbox + mailbox buffer size × 2 (case 16-bit) or + mailbox buffer size × 4 (case 32-bit)

The minimum RAM size that must at least be available for MR30 to be used is 16 bytes.

Furthermore, one additional task requires 11 bytes each without timeout function. But it requires 15 bytes each with timeout function.

A section named MR_RAM_DBG is provided in addition to the MR_RAM section. The MR_RAM_DBG section is necessary for using the OS's debugging functions. The RAM used for this section amounts to 17 bytes with the Task-pause functions being in use, or to 13 bytes with the Task-pause function being not in use.

7.3 Stacks

7.3.1 System Stack and User Stack

The MR30 provides two types of stacks: system stack and user stack.

- User Stack
  One user stack is provided for each task. Therefore, when writing applications with the MR30, it is necessary to furnish the stack area for each task.

- System Stack
  This stack is used within the MR30 (during system call processing). When a system call is issued from a task, the MR30 switches the stack from the user stack to the system stack (See Figure 7.4).

  The system stack use the interrupt stack(ISP).

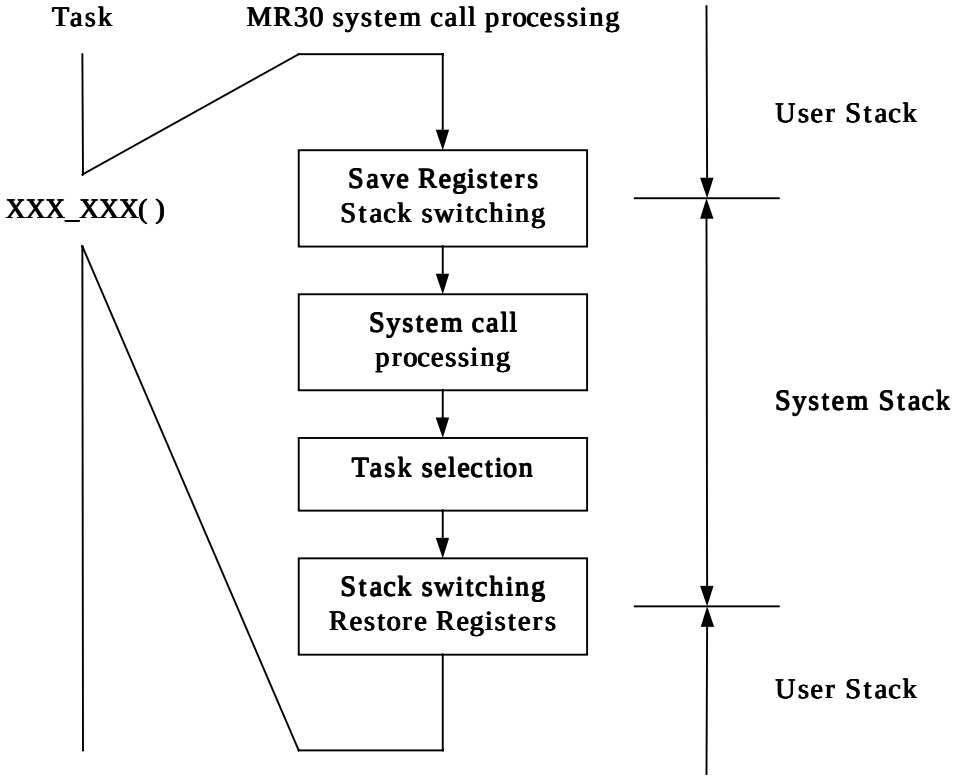


Figure 7.4 System Stack and User Stack

Switchover from user stack to system stack occurs when an interrupt of vector numbers 0 to 31 or 247 to 255 is generated. Consequently, all stacks used by the interrupt handler are the system stack.

Chapter 8 Sample Program Description

8.1 Overview of Sample Program

As an application example of MR30, this section shows a program to light (or turn on) the LEDs connected one for one to the M16C/80 series ports (P0 through P8). In this application example, each port is controlled by using each independent function.Table 2.1 lists these functions.

Table 8.1 Sample Program Function List

Function Name	Type	ID No.	Priority	Function
main()	Task	1	1	Wake up tasks sequentially from task2 to task4.
task2()	Task	2	2	Controls the input/output of port7.
task3()	Task	3	3	Controls the input/output of port8.
task4()	Task	4	4	Controls the input/output of port9.
cyh1()	Handler			Modifies the output data of port10

The main mask first sets ports 7, 8, 9and 10 for the output mode. Then task4 is activated from task2.

task2 sets initial value 0xff to port 7 (to turn on all ports) and enters a wait state where it waits until the system clock counts 25. Then it sets value 0x01 to port 7 to light the LED. It again enters a wait state where it waits until the system clock counts 25 and shifts the data value of port 7 one bit to turn on. This operation is repeated 8 times. (Example: 0000001 -> 00000010 -> 000001 00) This is in an endless loop.

Figure 8.1 depicts how port 7 is turned on.

task3 and task4 are processed in the same way as task2 except that the wait time is different from task2.

The values of variable pt10 and port 10 are modified in the cyclic handler cyh1(). While shifting the value of variable pt10 one bit at a time, the cyclic handler transfers the resulting value to port 10 to make it lit by the LED.

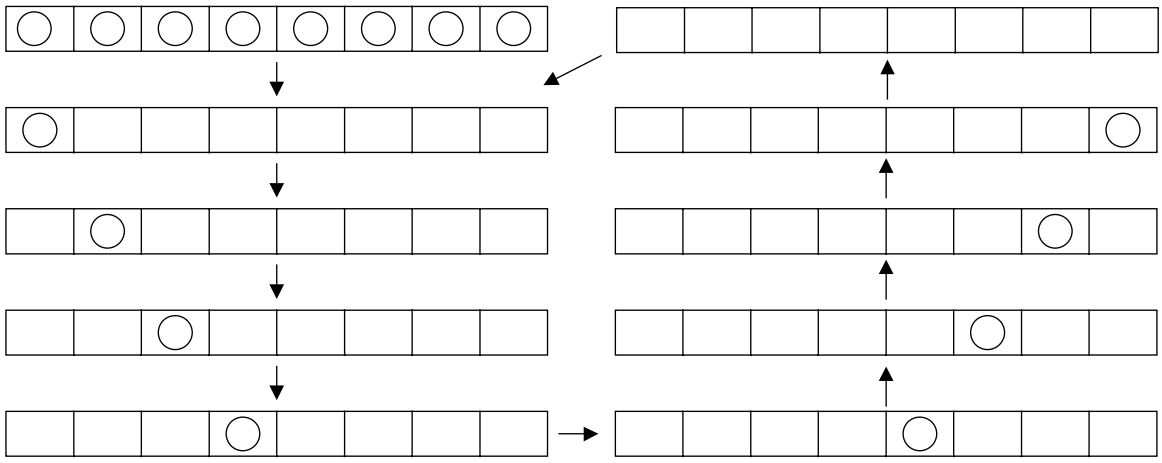


Figure 8.1 LED illumination Status

8.2 Program Source Listing

```
 1/***********************************************************************
 2
 3       COPYRIGHT(C) 2003 RENESAS TECHNOLOGY CORPORATION
 4       AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 5
 6              sample program
 7       $Id: demo.c,v 1.7 2003/08/22 12:59:49 muraki Exp $
 8
 9***********************************************************************/
10
11#include <stdio.h>
12#include <mr30.h>
13
14#include "id.h"
15
16#pragma ADDRESS PD7     3efH
17#pragma ADDRESS PD8     3f2H
18#pragma ADDRESS PD10    3f6H
19
20#pragma ADDRESS P7      3edH
21#pragma ADDRESS P8      3f0H
22#pragma ADDRESS P9      3f1H
23#pragma ADDRESS P10     3f4H
24
25char PD7,PD8,PD10;
26char P7,P8,P9,P10;
27
28char pt7,pt8,pt9,pt10;
29
30void  main()
31{
32#pragma ASM
33       bset    2,0AH
34       mov.w   #0FFH,3f3H
35       bclr    2,0AH
36#pragma ENDASM
37       PD7 = PD8 = PD10 = 0xff;
38
39       sta_tsk(ID_task2,1);
40       sta_tsk(ID_task3,1);
41       sta_tsk(ID_task4,1);
42}
43
44void task2()
45{
46       int     k;
47
48       P7 = 0xff;
49
50       while(1){
51              dly_tsk(25);
52              pt7 = 0x01;
53              P7 = pt7;
54              for(k=1; k<=8; k++){
55                     dly_tsk(25);
56                     pt7 <<= 1;
57                     P7 = pt7;
58              }
59       }
60
61}
62
63void  task3()
64{
65       int k;
66       P8 = 0xff;
67
68       while(1){
69              dly_tsk(50);
```

```
 70              pt8 = 0x01;
 71              P8 = pt8;
 72              for(k=1;k<=8;k++){
 73                      dly_tsk(50);
 74                      pt8 <<= 1;
 75                      P8 = pt8;
 76              }
 77      }
 78}
 79
 80void task4()
 81{
 82      int k;
 83      P9 = 0xff;
 84
 85      while(1){
 86              dly_tsk(100);
 87              pt9 = 0x01;
 88              P9 = pt9;
 89              for(k=1;k<=8;k++){
 90                      dly_tsk(100);
 91                      pt9 <<= 1;
 92                      P9 = pt9;
 93              }
 94      }
 95}
 96
 97void cyh1()
 98{
 99      if(pt10 == 0)
100              pt10 = 0x01;
101      P10 = pt10;
102      pt10 <<= 1;
103}
```

8.3 Configuration File

```
 1 //************************************************************************
 2 //
 3 //     COPYRIGHT(C) 2003 RENESAS TECHNOLOGY CORPORATION
 4 //     AND RENESAS SOLUTIONS CORPORATION ALL RIGHTS RESERVED
 5 //
 6 //     MR30 System Configuration File.
 7 //     $Id: smp.cfg,v 1.8 2003/08/22 12:59:49 muraki Exp $
 8 //
 9 //************************************************************************
10
11 // System Definition
12 system{
13       stack_size            = 1024;
14       priority             = 10;
15       system_IPL            = 4;
16       message_size          = 16;
17       timeout              = NO;
18       task_pause            = NO;
19 };
20 //System Clock Definition
21 clock{
22       mpu_clock             = 10MHz;
23       timer                = A0;
24       IPL                  = 4;
25       unit_time             = 100ms;         // ms
26       initial_time          = 0:0:0;
27 };
28 //Task Definition
29 task[1]{
30       entry_address         =     main();
31       stack_size            =     100;
32       priority             =     1;
33       initial_start         =     ON;
34 };
35 task[2]{
36       entry_address         =     task2();
37       stack_size            =     100;
38       priority             =     2;
39 };
40 task[3]{
41       entry_address         =     task3();
42       stack_size            =     100;
43       priority             =     3;
44 };
45 task[4]{
46       entry_address         =     task4();
47       stack_size            =     100;
48       priority             =     4;
49 };
50 // Cyclic Handler Definition
51 cyclic_hand[1]{
52       interval_counter       =     150;
53       mode                 =     TCY_ON;
54       entry_address         =     cyh1();
55 };
```

Chapter 9 Separate ROMs

9.1 How to Form Separate ROMs

This chapter describes how to form the MR30's kernel and application programs into separate ROMs.

Figure 9.1 shows an instance in which the sections common to two different applications together with the kernel are allocated in the kernel ROM and the applications are allocated in separate ROMs.

Here is how to divide a ROM based on this example.

4. System configuration

Here you set up a system configuration of application programs.

Here, descriptions are given on the supposition that the system configuration of two application programs is as shown below.

	Application 1	Application 2
The number of Tasks	4	5
The number of Eventflags	1	3
The number of Semaphores	4	2
The number of Mailboxes	3	5
The number of Fixed-size memorypools	3	1
The number of Cyclic handlers	3	3

5. Preparing configuration files

You prepare configuration files based on the result brought by setting up the system configuration.

- maxdefine definition

You specify the greater of the two numbers of definitions as to the respective applications for a value to be set in the maxdefine definition division.Thus the individual items must be equal in number to each other in these applications.

e.g.

```
maxdefine{
        max_task        = 5;
        max_flag        = 3;
        max_sem         = 4;
        max_mbx         = 5;
        max_mpl         = 3;
        max_cyh         = 3;
};
```

No means is available to deal with variable-length memory pools in the maxdefine definition. So if you use the variable-length memory pool functions in either of two applications, give the same definitions of variable-length memory pools in the two configuration files.

- system definition

You need to make the following items, which are dealt with in the system definition, common to two applications.

- message_size
- timeout
- task_pause
- priority

- clock definition

- initial_time
  The value assigned to this item in one of two applications can be different from its counterpart. Avoid defining this item in one application and omitting it in the other application. Be sure to deal with this item in the same manner, either define or omit, in two applications.

- task definition

- initial_start
  Switch this item ON only in the task first started up after the System is stared up, and switch this item OFF in any other tasks.

- variable_memorypool definition

  Deal with this item in the same manner, either define or omit, in two applications. Avoid defining this item in one application and omitting it in the other application.

Other definitions, though different from each other between two configuration files, raise no problem.

6. Changing the processor mode register

You change the processor mode register for a startup program in compliance with the system.

7. Preparing application programs

You prepare two application programs.

8. Locating respective sections

Programs to be located in the kernel ROM and in the application ROM are given below.

- Programs to be located in the kernel ROM
  - Startup program (MR_KERNEL section)
  - MR30's kernel(MR_KERNEL section)
  - Programs common to two applications(program section)

This example assumes that the task identified by 1 is a program common to two applications. Locating a common program in the application ROM raises no problem. With a common program located in the kernel ROM, the system calls given below cannot be issued, so be careful.

can_wup, get_tid, pget_blf, pget_blk, pol_flg,

prcv_msg, rcv_msg, trcv_msg, twai_flg, wai_flg

To issue these system calls from a common program, locate it in the application ROM.

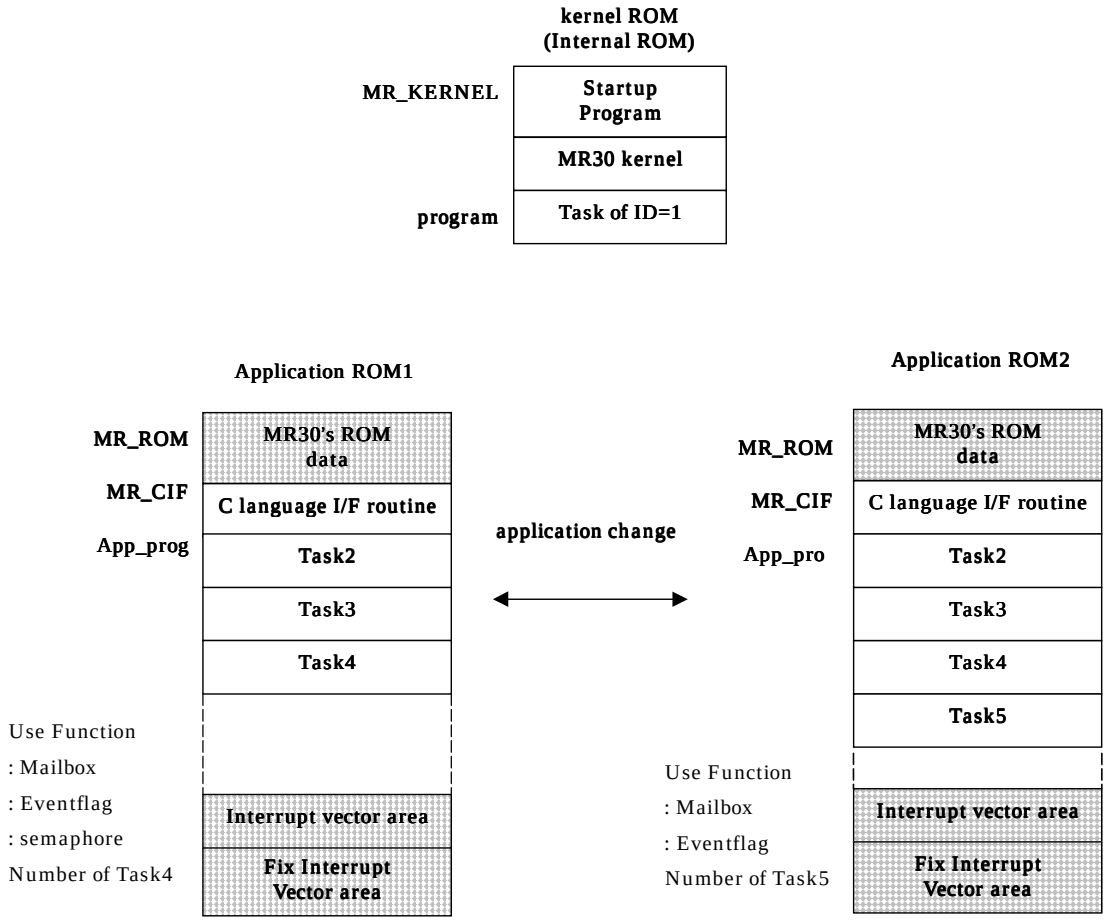


Figure 9.1 ROM separate

- Programs to be located in the application ROM
  - MR30's ROM data (the MR_ROM section)
  - C language I/F routines (the MR_CIF section)
  - Application programs (the app_prog section)
  - Interrupt vector area (the INTERRUPT_VECTOR section)
  - Fixed interrupt vector area(FIX_INTERRUPT_VECTOR section)

- How to locate individual programs is given below.
  - Changing the section name of user program

  In dealing with application programs written in C language, you change the section name of the programs to be located in the application ROM by use of #pragma SECTION as shown below. In NC30, the section name of user program, if not given, turns to program section. So you need to assign a different section name to the task you locate in the application ROM.[70]

[70] You need not change the names of sections for tasks to be located int the kernel ROM.

```
#pragma SECTION program app_prog/* Changing section of program */
/* The section names of task2 and task3 turn to app_prog */
void task2(void){
                :
}

void task3(void){
                :
}
```

♦ Locating sections

Here you change the section files (c_sec.inc, asm_sec.inc), and set addresses of programs you locate in the application ROM. In this instance, the respective first addresses of the sections given below must agree with each other between two applications.

- MR30's RAM data (MR_RAM, MR_RAM_DBG section)
- MR_HEAP section
- MR30's ROM data(MR_ROM section)
- Interrupt vector area(INTERRUPT_VECTOR section)

Settings of the section files are given below.

```
.section MR_RAM_DBG,DATA        ; MR30's RAM data
.org 500H                       ; The address common to two applications
.section MR_RAM,DATA            ; MR30's RAM data
.org 600H                       ; The address common to two applications
        :
.section MR_HEAP,DATA           ; MR30's RAM data
.org    10000H                  ; The address common to two applications
        :
.section MR_ROM,ROMDATA         ; MR30's ROM data
.org    0e0000H                 ; The address common to two applications

.section MR_CIF,CODE            ; C language I/F routine

.section app_prog,CODE          ; Use Program

.section INTERRUPT_VECTOR       ; Interrupt Vector
.org    0ffd00H                 ; The address common to two applications
```

The memory map turns to give below.(See Figure 9.2)

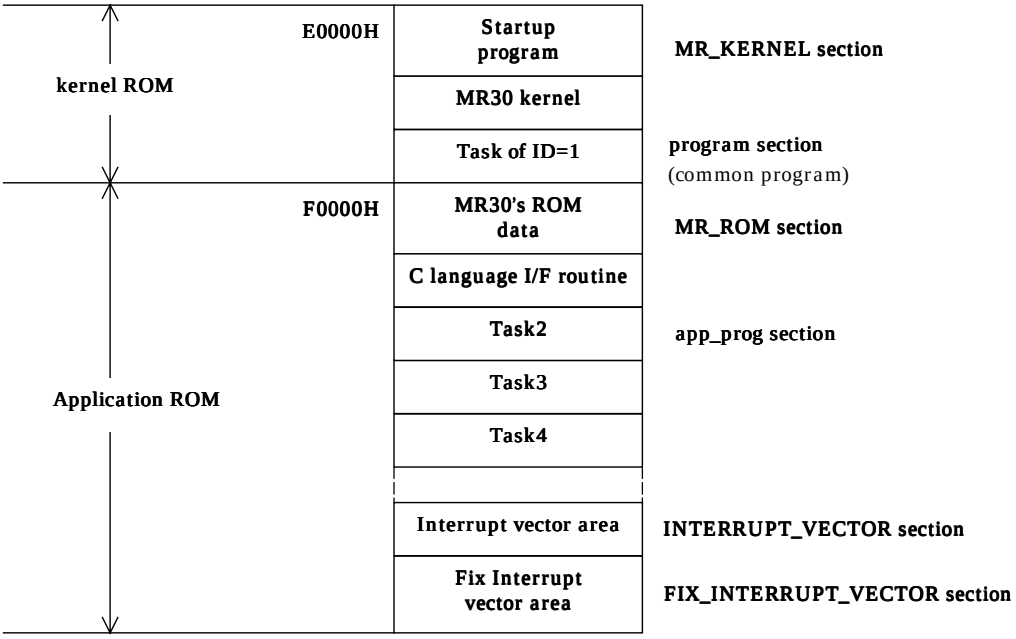


Figure 9.2 Memory map

9. **Executing the configurator cfg30.**

10. **Create an mrc file in which every system call is described. (Compiling the source program creates a file having the extension mrc in the work directory. Create an mrc file making reference to this.) Executing make clean in makefile created by cfg30 deletes the mrc file, so be careful.**

11. **Generating a system**

    You execute the make command to generate a system.[71]

12. **Carrying out steps 7 through 11 with respect to application 2 allows you to generate the system for application 2.**

The steps given above allows you to form the separate ROMs.

[71] If the file mrtable.a30 is not held in the current directory, execute make command to generate a system.

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